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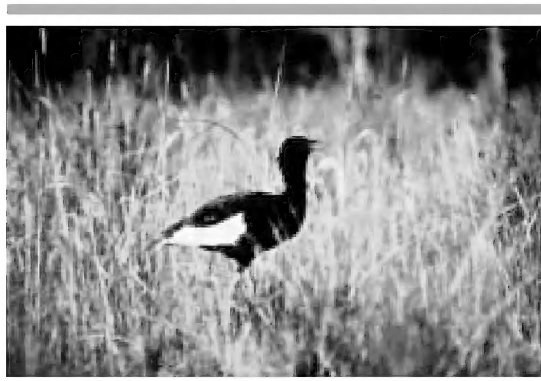
Summaries of Ph.D theses on birds






Bombay Natural History Society

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ENVIS

ENVIS (Environmental Information System) is a network of subject specific nodes located in various institutions throughout the country. The Focal Point of the present 25 ENVIS centres in India is at the Ministry of Environment and Forests, New Delhi, which further serves as the Regional Service Centre (RCS) for INFOTERRA, the global information network of the United Nations Environment Programme (UNEP) to cater to environment information needs in the South Asian sub-region. The primary objective of all ENVIS centres is to collect, collate, store and disseminate environment related information to various user groups, including researchers, policy planners and decision makers.

The ENVIS Centre at the Bombay Natural History Society was set up in June 1996 to serve as a source of information on *Avian Ecology* and *Inland Wetlands*.

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Cover Photograph: Collared Scops-Owl *Otus bakkamoena* by Dr. G. Maheswaran

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Preface

Ph.D. or the Doctor of Philosophy is the highest degree in the academic world. In most advanced countries, there are rigorous tests before a candidate is enrolled for a Ph.D. Sadly, such tests are lacking in many institutes in India, as a result of which the quality of research is compromised. In India, Ph.D. is a sort of *mantra* for going up in the hierarchy. It is now almost mandatory to possess this degree when applying for a lecturer's post in a university. It is not known how effective this rule is in attracting good teachers.

Like any degree, Ph.D. is also a learning process – perhaps the first step for serious academic pursuit. However, many people stop growing intellectually once they get a Ph.D. degree. For such people, getting a degree is the ultimate aim, so a prefix 'Dr.' can be added to the name.

Despite all the effort invested in a Ph.D. thesis, it is still what we call 'grey literature'. A thesis has low value unless it is published, either in book form or in papers in peer-reviewed journals.

Like any grey literature, a thesis tends to disappear into thin air (despite claims by some universities that they keep and catalogue all theses) and is not easily available. Sometimes extremely valuable information is present in a thesis that should be available to others for consultation, for instance, status survey of rare species or population densities of birds in a particular forest. Such data are valuable for other researchers to compare the status of particular species/groups across years and across sites. If papers are published in good journals then the data is available. If good papers are not published, valuable data is lost in a thesis that is not accessible to most researchers. A couple of years ago, while doing literature search on the Sarus crane, I came to know that a thesis on Sarus was submitted in a Gujarat University about 30 years ago, but till now I have not been able to get hold of it.

Looking at the difficulty of accessing theses, I feel that there should be a system in place wherein theses of a particular subject are kept and made available to other researchers. Much like the ENVIS centres on different subjects, different institutes can become repositories of theses and research papers on a particular subject. In the BNHS, we are planning to get copies of all theses on Indian birds, submitted in India or abroad. At present, we have about 33 theses. I know many more were submitted during the last 25-30 years. In this issue, we give summaries of theses that we have in our

library. We request the readers to write to us if they know of any other thesis submitted on birds. We also request that if your thesis is not included in this list, please send us a copy. Hundreds of people consult the BNHS library every year. Theses are kept in the Reference section so they cannot be taken out, and are available only for consultation. We do not allow photocopying, to avoid any 'stealing'of data! I must add here that once a thesis is accepted and a candidate gets the Ph.D. degree, the thesis is public property. Anyone can quote the thesis, giving proper acknowledgement (but no one has a right to photocopy the whole thesis without the permission of the author).

My sincere advice to researchers - publish papers from your thesis in good peer-reviewed journals. This way, your work will be known to other researchers and moreover, no one can 'steal' your unpublished data. A scientist is known from his/her published work, not by the number of days spent in a laboratory or field. An unpublished thesis or a report has very little value. It gathers dust in some forgotten cupboard and becomes food for silverfish, not food for thought.

Asad R. Rahmani

- Please note that we have compiled and copied summaries of theses verbatim with only minor editorial changes. We have not added or subtracted anything.
- While quoting, please give reference of the thesis, and not of BUCEROS (Vol.6. No. 3. 2001). It is just a compilation of summaries.
- You will notice that many Ph.D. theses on birds are missing as we do not have copies in the BNHS library. Kindly send a copy of your Ph.D thesis if it is not included in this volume. Thank you!

CONTENTS

TITLE **The birds of Gir Forest:The ecology and behaviour of vultures in Gir Forest**
STUDENT **Robert B. Grubh**
GUIDE **Dr. Sálim Ali**
YEAR **1974**
UNIVERSITY **Bombay University**

Summary

The ecology and behaviour of three species of vultures of the genus *Gyps,* namely, *G. bengalensis, G. indicus,* and *G. fulvus,* were studied in Gir Forest, Western India, from September 1970 to July 1972. The study led towards an understanding of plumage variations and field identification of vultures, their status and distribution in the Gir, feeding habits, population and the factors which make it possible for the three species to co-exist. The study also enabled an assessment of the impact of the association of vultures with the decreasing population of the Asiatic lion in the Gir, its only remaining stronghold.

As even standard Indian ornithological literature includes inadequate field description of vultures, I have, using my protracted field experience, prepared keys and tables to distinguish the different species at various plumage stages.

The status and distribution of *Gyps* vultures in the study area was determined by recording the local distribution, migratory habits and comparative abundance of the three species. The methods employed for the study of these aspects comprised (i) observation of vultures at carcasses, in flights and at roosts, and (ii) marking of individual vultures and random re-sighting of them.

Feeding habits including frequency of feeding, forage flights and how vultures detect food, utilization of food and mode of feeding, and food requirement, were studied by observing free ranging birds as well as birds in captivity. Free ranging birds were observed at carcasses, roosts, and in flight. Captive birds were observed under controlled conditions only to determine approximate individual food requirement. All the birds used for the experiments were captured from the Gir, and the experiments too were conducted within the Gir.

The extent of possible competition for food between lion and vultures was estimated through observations at lion kills. Since human beings often interfered with lion kills which in turn created conditions favourable for vultures to reach lion kills, it was necessary to study the effect of human influence on the inter-relationship between lion and vultures.

Two different types of sampling estimates were employed to assess the population of vultures occurring within the study area. The first estimate was based on the number of vultures sighted at each carcass observed in different parts of the Gir and during different periods of the year. The second estimate involved counting of vultures in forage flights from hill-tops in different parts of the Gir in eight successive months. The results from both the estimates were significantly close.

Since three species of vultures of the same genus occur together in the Gir, I analysed relevant ecological factors to determine whether any form of ecological isolation exists among them, and if not whether any other factors facilitate the coexistence of these closely related forms. The additional data required for the analysis mainly concerning inter and intra-specific behaviour were procured by field observation, especially at feeding sites.

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TITLE **Ecological problems relating to birds: Ecology and behaviour of the Black-and-Orange Flycatcher *Muscicapa nigrorufa* (Jerdon).**
STUDENT **Mohammed Ali Reza Khan**
GUIDE **Dr. Sálim Ali**
YEAR **1977**
UNIVERSITY **Bombay University**

Summary

The Black-and-Orange Flycatcher *Muscicapa nigrorufa* (Jerdon), (Muscicapinae: Muscicapidae, Class Aves) is an endemic passerine bird of the Western Ghats of Southern India. The species has so far been reported uncommon, and very little information was available on its status and distribution. Also the taxonomy of the

species remained uncertain in the absence of information on the juvenile plumage and other details. Moreover, the flycatcher-behaviour of this species had been doubted by many earlier workers, who conjectured that it was more closely related to Timaliine Babblers.

The thesis reports on a two-year long field study of the Black-and-Orange Flycatcher in the Western Ghats especially in the Nilgiris (Tamil Nadu) from September 1974 to September 1976. The following aspects were studied at length: The entire distributional pattern and status were determined in the Nilgiris and in other parts of the Western Ghats starting from the Biligirirangan Hills in Southern Karnataka down to Kanyakumari in Tamil Nadu, including parts of Kerala falling with the Western Ghats.

The habitat of the bird, its food and feeding habits and its typical behaviour were intensively studied. Song and call-notes, territorial behaviour and pre-nesting activities were observed and data recorded for two entire years. Breeding biology including nest building, laying, clutch size, incubation, hatching, nestling periods, parental care, history of the juveniles and breeding success were thoroughly investigated. The juvenile plumage was observed in live birds and specimens and conclusions drawn. On the basis of above mentioned observations it is concluded that the Black-and-Orange Flycatcher does not resemble any one of the Timaliine Babblers but in fact shows complete identity with the Muscicapine flycatchers.

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TITLE **Ecology and Biology of certain species of Indian Babblers (*Turdoides* spp.) in Malabar**
STUDENT **V.J. Zacharias**
GUIDE **Dr. D.N. Mathew**
YEAR **1978**
UNIVERSITY **Calicut University**

Summary

Three species of the genus *Turdoides* viz. *T. affinis* or the White-headed Babbler, *T. striatus* or the Jungle Babbler and *T. subrufus* or the Rufous Babbler occur sympatrically in many parts of Malabar.

In the Calicut University campus and at Chelannur near Calicut city where intensive study was conducted, the former two species occur together as residents. The White-headed Babbler is more frequently seen in the open grasslands and scrub jungles than the Jungle Babbler which lives in the closed canopy woodlands and other areas with plenty of plant cover. The Rufous Babbler spends most of its time under the cover of thickets in the edges of forests and estates. In this thesis, the stress is on the ecology of the White-headed Babbler with some comparative data about the Jungle Babbler. There are a few observations on the Rufous Babbler also. In the study area White-headed Babblers live in flocks of 3-14 birds and Jungle Babblers in flocks of 4-23 birds. Members of the groups of both species jointly defend their groups home range and territory. The home-ranges of the two species overlap slightly. They have some neutral areas of the home range where members of more than one group and species can feed together peacefully. But each flock has a well protected core area within its home range which is used for nesting and where only the members of the owner group are tolerated. With few exceptions the other conspecific, congeneric and unrelated species of birds are driven out of the core areas by the members of each flock jointly. Both species have the sentinel system for the defence of the groups. When the flocks forage or rest, an experienced member of the flock acts as a sentinel or a sentry watching out from a suitable perch and warning the group members by suitable vocalisations about the movements of potential predators and other intruders. Sentinel duty is shared by the members of the flock, but the breeding birds spend more time as sentinels. The sentinels of the Jungle Babbler perch higher than those of the White-headed Babbler. I have divided the habitat of the babblers in the campus into four biotopes or subhabitats viz. the open fields close to human habitation, the open scrub jungles and grass lands, the closed canopy woodlands and the highly disturbed woodlands with sparse undergrowth. White-headed Babblers are found in the first, second and fourth biotopes and Jungle Babblers in the third, second and fourth types in that order. The absence of White-headed Babblers in the closed canopy woodlands and of Jungle Babblers in the vicinity

of human habitation appear to be factors which help in their ecological isolation in this locality. However, in the less disturbed villages in Chelannur and Thenhippalam, Jungle Babblers also move in the compounds of houses. Both species of babblers have similar rhythms of activities. Neither has a clearly marked site for midday roost, but both have distinct sites on trees on which they roost at night. There are many species of trees which are used as sites for nightly roosts by both species of babblers, but Jungle Babblers perch higher at the roosts and are not seen to roost on *Calycopteris* or the Strychnine tree. White-headed Babblers are not observed to roost on Ficus trees.

Members of the groups of both species indulge in clumping and allopreening of flock mates. There is some evidence suggesting that the breeding male and its female partner are the dominant members of the flocks of the White-headed Babbler. A similar hierarchical organization was observed in the Jungle Babbler too at Delhi (Gaston, 1977). Both species have a number of vocalisations which coordinate the movements of the group. The calls of the White-headed Babbler are more musical. Young birds of both species indulge in similar playful activities.

Food and feeding behaviour

The White-headed Babbler and the Jungle Babbler have closely similar feeding behaviour, and they have many items of animal and vegetable food in common. Of the two, the Jungle Babbler has a larger bill. It often hammers the larger items of prey and swallows them whole, whereas the White-headed Babbler tears large items to small bits before swallowing. Birds of both species feed on insects of Orthoptera, Isoptera, Coleoptera, Hymenoptera, and Lepidoptera, the wild fruits and berries of plants like *Lantana*, *Passiflora*, *Physalis*, and *Macaranga* and the starch of Cassava and rice. Cassava is grown throughout the year in the study area and the starch of its tubers is consumed in small quantities throughout the year by both species. In the campus and Chelannur, White-headed Babblers supplement their diet with items gleaned from the premises of kitchens and the Jungle Babblers do the same thing in the villages. The differences in the microhabitats of the two species are reflected in their stomach contents. The White-headed Babbler which feeds frequently in the open fields and compounds of houses takes more of termites, bugs and hymenopterans and the Jungle Babbler which feeds in or close to the woodlands and shady areas show more of Coleoptera in its stomach contents. The White-headed Babbler hops about on the cement walls of compounds and houses in the course of its foraging trips. Even though both species consume some of the crops like Cassava, Paddy and Peas they take them in so small quantities that neither species can be considered as a pest.

Breeding Biology

Both species of babblers breed irregularly in the study area in most of the months of the year, but egg-laying has not been recorded in the month of July in either species. The peak period of egg-laying is April in the White-headed Babbler and February in the Jungle Babbler. This break in July helps the babblers to avoid incubation in torrential rains. Intensive rain can flood the nests. No elaborate courtship ceremonies have been observed in either species and only a single pair of birds or rarely one male and two females of each group are involved in pairing and the production of the eggs in both species. The other members of the flock act as helpers in nesting.

With few exceptions, the same species of trees are used for nesting by both species of babblers. The nests of the Jungle Babbler are placed in forks situated higher from the ground. The eggs of both species have the same colour; the clutch size and size and weights of eggs are slightly higher in the Jungle Babbler. The nestlings of the two species are very similar in colour. The incubation period, nestling period and care of the fledglings are similar in both species of babbler. In the White-headed Babbler the juveniles usually stay in the natal groups, but in rare cases some juveniles leave their parents and join new groups. This aspect was not studied in the Jungle Babbler in my study area. In Delhi Gaston did not observe the juveniles of the Jungle Babbler leaving their natal group.

Both species of babblers in my study area were troubled by predators like the Rat snake, the House crow, the Jungle crow, the Mongoose and the domestic cats. The Pied Crested Cuckoo parasitized the nests of the White-headed Babbler and the Hawk Cuckoo those of the Jungle Babbler. But such cases were very rare in my study area. Fortytwo percent of the eggs laid, produced fledglings in theWhite-headed Babbler and 43% in the Jungle Babbler. Generally, the larger groups of the White-headed Babbler (which lived in areas with access to better sources of food) raised more young. This aspect could not be studied in the Jungle Babbler.

Age, appearance and moult of feathers

The iris is darker upto 3 months of age in both species of babblers. The tarsi are paler and the feathers without streaks upto 4 months in White-headed Babbler. The tips of the primaries are rounded in the first and second year White-headed Babblers and the wings and tails attain the adult length by the second year in both species. Based on such characters, the age structure of the populations of both species can be crudely estimated in the field.

The juvenile White-headed Babbler undergoes its first moult at 3 months. In the juveniles raised in the later months of the year, the postjuvenal moult may be incomplete.

Both the White-headed Babblers and the Jungle Babbler moult their body and flight feathers once every year. Moult of the body feathers of both species is characterized by its long duration at the population level (March to November in the White-headed Babbler and February to November in the Jungle Babbler) and slow tempo. Moult is not temporally separated from breeding. The adult birds of both species wear the plumage of the same colour throughout the year. The moult of flight feathers in both species conforms to the general pattern of flight feather moult of the passerine birds. The rectrices of both species moult.

Centripetally and in both species, the moult of the primaries and their upper greater coverts, proceed systematically from the proximal to the distal end. The secondaries moult from both ends and the tertiaries moult less regularly and within no definite temporal relation to the progress of moult in the rest of the remiges.

Population

In the Calicut University campus, White-headed Babblers live in groups of 3-14 and Jungle Babblers 4-23 birds. The number of individuals in groups of both species, fluctuated frequently. Groups of White-headed Babblers living close to the compounds of houses were larger and had a better rate of increase. The most frequently observed group size of the White-headed Babbler was between 4 and 8, only four groups reached the maximum size of 14. None of the groups contained 14 members for longer than 8 months, and after reaching this size all of them underwent a reduction of size. The groups with 10 or less White-headed Babblers were more persistent. Jungle Babblers lived in the less disturbed woodland and sheltered areas of the campus and this may be one of the reasons for their larger group size. On the whole, the overall tendency of both species of babblers was to increase their numbers gradually during the period of study.

Intergroup movements of birds of all age classes were noticed frequently in the White-headed Babbler. There were cases of the newly fledged birds, the 1st and the 2nd years, the breeding and the non-breeding adult birds leaving one group and joining another. While there were more movements of birds from areas with inferior resources of food to those with better food supply, the reverse type of intergroup movements was also recorded. This suggests that food is not the only factor causing intergroup movements. These movements may be a means of natural regulation of the group size of the White-headed Babbler. These movements also help in preventing inbreeding and perhaps give some of the low ranking birds of the groups better chances of pair formation and breeding. This aspect was not studied in detail in the Jungle Babblers of the study area; In Delhi, Gaston did not observe such frequent or extensive interchange of birds of different age classes.

The limited data gathered on the age composition suggested that the different age classes were present in more or less equal numbers in the groups of the White-headed Babbler of the campus. This may be due to the fact that only two or three birds bred in a group and that birds of all age groups moved from group to group. The rate of reproduction and annual turnover of the young, were not very high and predators like the Rat snakes, crows and mongooses reduced the population of juveniles and first year birds.

In the two groups of White-headed Babblers which were examined by shooting, the sex-ratio was 2 : 1 in favour of males, whereas in 183 adult birds shot over two years both sexes were present in equal numbers. In 215 Jungle Babblers shot over 3 years the sex ratio was 1 : 1. Both age-composition and sex ratio of White-headed Babblers have to be studied by more extensive examinations.

The Economic Status

The activities of the White-headed Babbler in the study area range from harmful to beneficial with respect to agricultural economy. In isolated small plots of peas, groups of this bird could do some damage, and so also in the yards of rice mills and houses where rice or paddy is spread out for drying. They occasionally feed on the apples of cashew, ripe fruits of mango and carpels of jackfruit and grains of bajra. Broken bits of raw tuber of cassava are eaten by these birds. All these above mentioned items are consumed by the Jungle Babbler. Both

these species are omnivores which never seem to consume a particular item of food in large quantities so as to cause any serious depletion of its supply. Among the animal items consumed by these two species, the garden lizards and four families of insects may be considered to be useful to man and feeding on them may be a disservice.

The most important service these two species of Babblers do to man in the study area is the removal of termites from the environs of human habitation. In all, White-headed Babblers I have studied consumed 15 families of insects harmful to man, and Jungle Babblers 19 of them.

In the process of feeding on nectar, the babblers may be helping in the pollination of flowers. As the seeds of *Macaranga* taken from the intestines of both of these babblers germinated, it is suspected that they help in the dispersal of the seeds of this plant. Leaves of *Macaranga* are important leaf manure frequently used by the farmers. The exact proportion in which the various items of food are consumed by these birds has not been studied, but the fact that they have considerable potential for meritorious service to agriculture cannot be disputed.

The habitats of both species of babblers in the Calicut University campus are undergoing rapid destruction and modification. So far the populations of both have shown a tendency to increase. But if the destruction of plants like *Macaranga*, Cashew and *Calycopteris* are continued at the present rate both of these species will be adversely affected.

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TITLE **Synecological studies on the specialised nectar-feeding birds and bird-flowers in the Nilgiris**
STUDENT **Priyadarshini Davidar**
GUIDE **Dr. Sálim Ali**
YEAR **1979**
UNIVERSITY **Bombay University**

Summary

Research in bird pollination in the Indian subcontinent was initiated by Ali (1931, 1932), and later followed up by Kannan (1966). These studies were mainly concerned with the structural adaptations of the nectar-feeding birds and the ornithophilous flowers. With the recent emphasis on ecology, the need was felt to study the synecology of the specialised nectar-feeding birds and ornithophilous or 'bird-flowers'.

The study was conducted in the Nilgiri Hills of south India which lie between latitude 11° 12' and 11° 43' N, and longitude 76° 14' and 77° 1' E. The varied topography and elevation with the consequent effect on the meteorology and climate in different parts of the Nilgiris, support different vegetation types ranging from the Southern Tropical Thorn Forest in the lowland rain shadow areas, to the Southern Montane Wet Temperate Forest in the high altitudes. The main study area was Coonoor situated at an elevation of 1800m above sea level, with a greater representation of montane flora than lowland flora. In this area intensive study was conducted on the synecological relationships between four species of specialised nectar-feeding birds belonging to three families - the Dicaeidae, Nectariniidae and the Zosteropidae, and seven species of bird-flowers of the family Loranthaceae.

The study covered three aspects of the relationship between the specialised nectar-feeding birds and the bird-flowers, namely the structural adaptations of the bird and the flower that promote nectar-feeding and pollination; the relative abundance and co-existence of four related species of birds in the area; and the ecological interactions between the bird and the flower and related manifestations like territoriality in the bird.

The structural adaptations of the bill and tongue of the birds to facilitate nectar-feeding and the modifications of the corolla of the bird-flower to facilitate nectar-feeding by the birds are described. The four species of specialised nectar-feeding birds - *Dicaeum concolor*, *Nectarinia minima*, *N. asiatica* and *Zosterops palpebrosa* have specialised adaptations of the bill and tongue for a nectar diet. The sunbirds *N. minima* and *N. asiatica*, which feed entirely on nectar and insects, have a greater specialisation for a nectar diet. *D. concolor* and *Z. palpebrosa* that take fruits in addition, are less

specialised for a nectar diet as compared with the sunbirds.

The relative abundance and habitat preferences of the four species of birds was assessed in different habitats, a natural shola forest, a degraded secondary growth area and a cultivated garden, by the line transect method, where the birds seen or heard from a fixed route through the study areas were recorded, at fortnightly intervals. The vegetation zone preferences of each species was recorded quantitatively and their feeding technique noted.

The most abundant species was *Z. palpebrosa* and *N. minima*, followed by *D. concolor* and *N. asiatica*, which visited only one species of bird-flower in the area. Of the factors responsible for flower preference - caloric content and flow of nectar, taste and colour are considered the most important (Stiles 1976). Other important factors are habitat of the plant species, flowering season, correlation of the bill with the corolla length and shape. A combination of the different factors is considered responsible for flower preference.

Territorial behaviour in nectar-feeding birds has been documented in many cases. Territory is the behavioural outcome of competition for some limited resource, especially food. *N. minima* males were territorial in the non-breeding cycle over a nectar source. Male territoriality in *N. minima* was held to be adaptive to increased fitness. *D. concolor* was also territorial over food resources. *N. asiatica* of this area were not observed to be territorial. *Z. palpebrosa* was not territorial and fed in loose flocks.

The extent of self-pollination in the species of Loranthaceae under study was investigated experimentally. With the exception of *D. neelgherrensis* and *M. parasiticus* the species with exploding flower buds displayed no self-pollination. Species whose buds open spontaneously are all, to an extent, self-pollinating. Insects appear to play a minor role in the pollination of *H. intermedia* and *D. memecylifolia.* Exploding flower buds in the Loranthaceae promote an exclusive relationship between the pollinator and the flower. However, species with and without the exploding mechanism in the bud, both attracted pollinators, and it is questionable whether the exploding mechanism gives a competitive advantage to the plant species in attracting pollinators.

The effect of the foraging pattern of the bird on the pollen flow in the community was investigated. Territorial birds would confine the pollen to the limits of the territory, whereas non-territorial birds would disperse pollen over a wider area. A plant taken as a single genetic unit, the data indicated that territorial *N. minima* and *D. concolor* contribute to a larger percentage of self- rather than cross pollination and limit the pollen flow to the territory, whereas *N. asiatica* and *Z. palpebrosa* would disperse the pollen over a wider area.

General observations and a study of the habitat and flower preference indicates that *N. asiatica* has possibly colonised this area fairly recently from lower areas. Of the bird-flowers, *D. falcata* with amplexicaul leaves, which is visited systematically by sunbirds in the lower elevations, is exploited rather sporadically for nectar by the birds in Coonoor. Its flowering season does not conform with the pattern of the other bird-flowers in this area, and this possibly indicates that this species may also have colonised this area rather recently.

In conclusion, the sunbirds and flowerpeckers play an important role in the pollination of Loranthacean species in the area. The White-eye is a more generalised feeder and contributes significantly as a supplementary pollinator of many of the Loranthacean species in this area, excepting *D. neelgherrensis*, which it mostly pollinates.

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TITLE **Comparative biology of Drongos (Family Dicruridae, Class Aves) with special reference to ecological isolation**
STUDENT **Lalitha Vijayan**
GUIDE **Dr. Sálim Ali**
YEAR **1984**
UNIVERSITY **Bombay University**

Summary

The widely examined and accepted principle, in recent years, of ecological isolation, originally known as "Gause's hypothesis", states that congeneric sympatric species must have different ecological requirements for their coexistence. The validity of this principle has been established in various groups of living beings from micro-organisms and plants to mammals.

Drongos (Family Dicruridae) have been selected for the present investigation with four species, the Gray drongo *Dicrurus leucophagus*, the Whitebellied drongo *D. caerulescens* co-existing in two different habitats — three of the four species, except the Whitebellied Drongo, in the tropical semi-evergreen forest at Thekkady (1850 m. elevation) in Kerala and all the four species in the dry deciduous scrub forest and plantations at Lower Camp (600 m) in Tamil Nadu. The field study was conducted from October 1978 to June 1981.

In order to examine the various factors relating to their ecology, a thorough study of the environment was done, especially at Thekkady. The availability of food with the abundance of insects and other invertebrates and the bird fauna were estimated periodically. Climatological factors were also noted.

Food and feeding habits were studied by standard field observations. Frequency of feeding from different strata and locations during different hours and months was recorded along with the time taken for each feeding trip, the food material collected (whenever identified) and the method of feeding on particular items. Rate of feeding of each species in different hours and months was noted to be different. Preferred strata of each species varied from one another. Feeding locations also were different, but less significantly. Time taken for the feeding trip showed still less variation with species. But the speed of feeding flight as well as distance from which insects were caught varied with species. Size of prey mostly depended on the size of the bird. Drongos were found to have very close relation with the mixed-species feeding flocks. Details regarding the dynamics of the feeding flocks, frequency of occurrence and feeding of each species of Drongo along with these flocks and its association with other species of Drongos as well as species other than Drongos were recorded. Factors affecting the association of species in mixed flocks and its significance are discussed.

The Bronzed and the Racket-tailed Drongos were observed breeding at Thekkady, and the Bronzed and the Whitebellied Drongos at Lower Camp. Breeding season of these species extended from February to September. Temperature, rainfall and availability of food supply appeared to be the important factors determining their breeding season. The pattern of pair-formation, pair-bond and details of territory were observed. Presence of a helper was noticed in many nests of the Bronzed Drongo and some nests of the Racket-tailed Drongo, to be taking part in all the activities of nesting cycle. Details regarding the nest including its structure, materials, location and construction, and also the clutch, incubation, nestling and fledgling periods were studied. Breeding success of each species was examined with the probable factors affecting it.

The phenomenon of ecological isolation and niche theory are discussed. Isolation while feeding was found to be mainly by the difference in the prey size (sometimes in the types or taxa also) based on the morphology of the species. Vertical stratification was also important in reducing competition between these species. The pattern of stratification was found to vary from species to species in different hours, months and also in different feeding combinations with or without other species. Feeding location, though it varied significantly in some cases, did not appear to be an important isolating mechanism. But variation in the feeding activity rhythm, speed of feeding flight and the distance from which insects were caught by the competing species might help in reducing competition. Niche breadth of each species in the two dimensions, the vertical feeding strata and the locations, and also niche overlap between species in these dimensions were calculated. The factors affecting niche breadth and niche overlap, such as morphology, habitat structure, availability of preferred food and presence of competing species are discussed. Breeding habitat variation was observed between the Racket-tailed and the Whitebellied Drongo, between which similarities were observed in the location of nest and some of the nesting materials. There was apparently no competition for the resources between the Racket-tailed and the Bronzed Drongo unlike between the Whitebellied and the Bronzed Drongo at Lower Camp, where partly inter-specific territories were maintained for reducing competition.

The different co-existing species of Drongos are thus found to have evolved different methods for reducing competition, such as difference in prey size, preferred feeding strata, feeding activity rhythm, speed and distance of feeding flight, breeding habitat, breeding territory and also by winter or local migration. These findings tend to support the principle of ecological isolation.

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TITLE **Ecology of the laughing thrushes of India with special reference to the endemic species**
STUDENT **Mohammed Anwarul Islam**
GUIDE **Dr. Sálim Ali**
YEAR **1985**
UNIVERSITY **Bombay University**

Summary

About 30 species of laughing thrushes occur in India, mainly in the Himalayas. Two of these species are endemic and occur in certain hill ranges of southern India. Extensive studies on the ecology of Indian Laughing Thrushes have not been reported. A great deal of work has been done on taxonomy and some work on breeding and general habits. The present thesis deals with a study of the ecology of the two south Indian endemic laughing thrushes, namely the Nilgiri Laughing Thrush *Garrulax cachinnans* and the Whitebreasted Laughing Thrush *Garrulax jerdoni* from May 1982 to mid March 1983 and July 1983 to August 1984. For comparative data, three and a half months of observations (20 March to 8 July 1983) were made on four Himalayan congeners, namely the Streaked Laughing Thrush *G. lineatus,* Whitethroated Laughing Thrush *G. albogularis,* Whitecrested Laughing Thrush *G. leucolophus* and the Striated Laughing Thrush *G. striatus.*

The major aspects of study taken up under this research programme were a) an understanding of the territory, vocalizations and general habits of the study species, b) their food and feeding habits and c) their breeding biology.

The study of vocalizations shows that the laughing thrushes have a large vocal repertoire. The calls are very loud and seem to have definite functions. Territorial behaviour was studied in the southern laughing thrushes. Preening, bathing, sunning/drying and roosting have been considered under general habits in the present study.

The study of food and feeding habits comprised identifying the food items, foraging methods, feeding locations, feeding heights, feeding rhythm and competition for food. Seasonality and fluctuations of their food items were studied round the year in the Nilgiris and for short periods in other places. No specific differences in feeding behaviour were evident between the two endemic laughing thrushes *G. cachinnans* and *G. jerdoni.*

The study of breeding biology of the laughing thrushes included the breeding season, nest building, laying, clutch size, incubation, hatching, nestling period and parental care. The south Indian laughing thrushes start breeding relatively earlier in the season than their Himalayan congeners, except *G. lineatus* which rears at least two broods, thus requiring an early start. Presence of helpers was noticed only at the nests of *G. albogularis* in the Himalayas. Self-destruction of the nests, though a rare phenomenon among birds, was found in three species of laughing thrushes: *G. cachinnans* and *G. jerdoni* in southern India and *G. striatus* in the Himalayas. The birds destroy their own nests after the nestlings leave as well as when eggs or nestlings are predated; sometimes even before laying eggs. Egg-eating behaviour by the parents was observed once in *G. jerdoni.* The present study finds no specific differences in breeding behaviour between the two southern endemic species.

The restricted occurrence of the endemic laughing thrushes only in a few hills of southern India and nowhere else in the peninsula has been attributed by some biologists to the disruption of their continuous distribution with the Himalayas by the geological changes through geotectonic action, as postulated in the Satpura Hypothesis by Dr. Sunder Lal Hora. This and other theories have also been discussed in the thesis.

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TITLE **Bird communities of the tropical dry-evergreen forests of Sriharikota**
STUDENT **Prakash Rao**
GUIDE **Mr. J.C. Daniel**
YEAR **1988**
UNIVERSITY **Bombay University**

Summary

Forests are basically dynamic ecosystems containing a diverse range of floral and faunal communities. The Tropical Dry Evergreen Forests (TDEF) of the Coromandel coast in south east India are a thin strip of coastal forests which are under tremendous

pressure due to various factors. It is believed that this forest type is today one of the most endangered ecosystems in the country. The remnant patch of TDEF at Sriharikota Island which is part of ISRO's SHAR Centre is of considerable interest as it is one of the last remaining patches of forest which is still in a relatively undisturbed condition. The present study has been undertaken to understand the bird community of the various habitats of the island.

The vegetation of the island is diverse and around 66% of the island is forested. The forest areas are chiefly confined to the northern and central sectors of the island. For the present study seven habitats were studied. These included the Dry Evergreen Forest (DEF), Dry Evergreen Thickets (DET), Regenerating Mixed Forest (RMF), Coastal Sand Dunes (CSD), and plantations. The major forestry plantations of the island included Eucalyptus, Casuarina and *Anacardium occidentale* (Cashew). The understorey of the forest vegetation was dense and quite impenetrable in certain areas except in the RMF plot at Jonangipalem. The DEF habitats ranged in height from 12-15 metres. Evergreen species included *Syzigium cumini*, *Strychnos nux-vomica*, and *Morinda tinctoria*. The understorey is thick and comprised of thorny elements like *Atlantia monophylla*, *Caesaria esculenta*, *Drypetes sepiaria*, *Catunaregum spinosa*, *Gmelina asiatica* etc.

The earlier ornithological survey of the island recorded 115 species in 1976-77. During the present study 203 species were recorded from the island and its environs. Other faunal resources included several species of small mammals like Bonnet Macaque, Jackal, Wild Boar, and Slender Loris. The avifaunal diversity of the island is varied. Of the 77 families of birds in the Indian subcontinent, 50 are represented in the island. 74 species of terrestrial birds were recorded during the present study. The number of species recorded in DEF, DET, RMF, CSD, Eucalyptus, Casuarina and cashew was 47, 40, 48, 30, 27 and 41 respectively. RMF plot had the highest number of species while Casuarina supported the lowest number. Densities of birds were higher during November, December and January when the forest patches were supplemented by the presence of terrestrial migrants.

12 species were common to all habitats that were studied. Some common species were Red Whiskered Bulbul, White Browed Bulbul, Common Myna, Common Iora, Tailor Bird, Blyth's Reed Warbler etc. Species specific to habitats included Black Capped Kingfisher, Ashy Minivet, Crimsonbreasted Barbet, Roseringed Parakeet and Green Pigeon. The Grey Junglefowl which is an endemic species in peninsular India had sizable presence in the island. Changes in avifauna abundance occurred mainly after the onset of the north east monsoon, when vast numbers of migrants occupied territories in the island. Bird densities were fairly low in the plantation plots as compared to the natural forest plots.

The vertical distribution of birds of the island showed that 50.4% individuals utilized heights up to 6 metres while 23.9% used heights over 13 m. The majority of the birds occupying the canopy layers (>13 m) occurred in the RMF plot at Jonangipalem where tree heights ranged up to 25 m.

Foraging behaviour of birds of the island was studied to understand community structure in relation to agitation. Insectivores formed the largest group (39 spp) followed by frugivores. Insectivores also accounted for 52.33% of prey attacks. The principal foraging manouevre used by birds was gleaning (76%).

Foraging heights in birds were grouped according to the vegetation strata. 85.25% birds foraged in the shrub (1-4 m) and sub-canopy (5-10 m) layers. Considerable overlap was noticed in the shrub and sub-canopy layers. Higher incidence of foraging at lower heights was attributed to the diversity of shrubs/bushes in the DEF/DET plots. Tree and Shrub were the major foraging substrates used by the birds (49.7%). In all 44 species of plants were utilized by foraging birds in three foraging guilds. Trees accounted for 22 spp. (50.1%) while shrubs were utilized by 19 spp. (43.18%).

Bird migration in the island occurs after the onset of the northeast monsoon. 30 species of migrants have been recorded of which Blyth's Reed Warbler, Greenish Leaf Warbler and Common Swallow were found to be very common. Earliest arrivals of migrant species was recorded in August while a majority (72%) wintered only after the onset of the northeast monsoon. Similarly, most departed from the island by end of March while about 5 spp. (20%) continued to occur till the first week of May. Species like Brown Shrike, Blyth's Reed Warbler, Greenish Leaf Warbler, occupy territories in the island in many habitats. Site fidelity was prevalent in these species as observed from band recapture data during the study. Two interesting migrant species were recorded from the island during the present study. Philippine Shrike and Ashy Minivet which were known to winter mainly in the Andaman and Nicobar Islands were recorded from the island in winter.

The conservation of the natural resources of the island in terms of protecting the existing forests should be examined in depth. The RMF habitat along the Buckingham Canal in the western part of the island is an important habitat for avifauna. Other areas of rich diversity which require protection include the DEF and the DET habitats. Habitat monitoring on a continuous basis or once in two years is essential to understand the changes taking place in the island ecosystem. Ecological aspects like hydrobiological studies, the role of dispersal agents in the island, surveys on mammals need to be taken up as future research topics to fully understand the ecosystem processes in Sriharikota Island.

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TITLE **The general ecology of raptors (Families Accipitridae, Strigidae, Class Aves) in Keoladeo National Park, Bharatpur**
STUDENT **Vibhu Prakash**
GUIDE **Mr. J.C. Daniel**
YEAR **1988**
UNIVERSITY **Bombay University**

Summary

Raptors are a group of apex species and are considered to be the indicators of the health of an ecosystem in which they occur. They feed on a variety of animals and sometimes they subsist entirely on rodents and other vermin of importance in the agricultural economy as well as in maintaining an ecosystem in dynamic equilibrium. Attempts have already been made, mostly in Europe and North America, to evaluate the status of raptors in the dynamics of an ecosystem. However in India, to date, studies on raptors have not received much attention.

The present study is the first attempt to gather simultaneously, information on the basic ecology of all the raptors that are found in an ecosystem. Data on the population and distribution; number of breeding and non-breeding species; habitat utilization; activity pattern and time budgeting; nesting density and distribution; nest site selection and building; clutch size and share of the sexes in incubation, nestling and fledgling periods; and hatching, nestling and nesting success of some species in detail and others in general has been collected.

Keoladeo National Park in Bharatpur was selected for the study on its own merit as one of the best waterfowl reserves and consequently, of avian predators in the world. Moreover, the study fits into or is an essential part of an in-depth system analysis of the ecosystem of the park where raptors are the major predators in the higher trophic level.

The field study was conducted from September 1984 to February 1988 and intensively from September 1985 to August 1986.

The population was estimated by transects on foot and on cycle along the bunds and the roads criss-crossing the park. The highest population was recorded in December in all the years, 95, 100 and 94, respectively in 1984-85, 1985-86 and 1987-88. The Shannon-Weiner species diversity index was consistently higher during the winters, whereas equitability was the lowest during this season.

To study the predator-prey relationship the population of the prey species, mainly waterfowl was also estimated every month. A significant positive correlation was seen between raptors and waterfowl population ($r = 0.99, 0.86$ and 0.89 during 1984-85, 1985-86 and 1987-88 respectively).

The distribution of raptors was studied by marking each sighting on a map. The migrants depend largely on the marshes and surrounding forest, whereas the residents prefer the terrestrial areas, thereby indicating niche partition between them. The migrants appear to have site fidelity as they occupy almost the same territories in subsequent years.

The habitat preference of raptors was studied by recording the species of tree where the bird was sighted, height at which the sightings were made and the activity at the time of observation. According to the phenological

condition of the perch and the whole tree, the perching trees were divided into three classes, namely, dry, top-dry and green.

The habitat preference of six dominant species namely Imperial Eagle (*Aquila heliaca*), Steppe Eagle (*Aquila rapax nipalensis*), Greater Spotted Eagle (*Aquila clanga*). Lesser Spotted Eagle (*Aquila pomarina*), Pallas's Fishing Eagle (*Haliaeetus leucoryphus*) and Marsh Harrier (*Circus aeruginosus*) was studied in detail. A very significant difference in the preference of tree species by all the raptors was noticed. Sympatric marsh-loving *Aquila* species although utilizing almost similar habitats, were segregated by their choice of different tree classes as well as different heights. The habitat preference index showed that *Aquila heliaca* and *Aquila clanga* prefer green *Mitragyna parvifolia*, whereas *Haliaeetus leucoryphus* and *Aquila pomarina* prefer dry *Mitragyna parvifolia*, *Aquila rapax nipalensis* had high preference for top-dry *Acacia nilotica* while *Circus aeruginosus* preferred dry *Zizyphus jujuba* (*mauritiana*).

Aquila clanga had the highest habitat niche breadth (B=309) probably owing to the even utilization of tree classes. *Aquila heliaca* and *Aquila rapax nipalensis* shared similar tree classes resulting in high niche overlap (= 71).

The food and feeding habits were studied by standard field methods. The food species diversity index, one dimensional niche breadth and niche overlap based on food items were calculated. The three marsh loving *Aquila* species preferred avian prey, while *Haliaeetus leucoryphus* and *Circus aeruginosus* preferred fish, and *Aquila pomarina*, mammals. *Aquila clanga* had the highest niche-breadth (B = 202), whereas *Haliaeetus leucoryphus* had the lowest (B = .031), suggesting the wide range of food items of the former and the narrow range of the latter. Kleptoparasitism among raptors and fish-eating birds was observed. In piracy, the dominance ratio showed existence of a hierarchy.

The time budget and activity pattern of *Haliaeetus leucoryphus* was studied for six and a half months and, four other species for three months following the focal animal method. *Haliaeetus leucoryphus* forage the most during pre-migration period, they rest mostly during nest building and soar the most during re-nesting period. It has definite soaring territories. *Aquila heliaca* and *Aquila rapax nipalensis* the two true migrants, show low foraging during March, whereas *Aquila clanga* and *Aquila pomarina*, the two residents, show high foraging during March.

The breeding biology of raptors was studied. The nests were searched for throughout the park and the locations were marked on maps. The nesting cycle was studied using a blind. Ten species of raptors nested in the park. Two species, namely *Aquila clanga* and *Aquila pomarina,* nested for the first time inside the park, the latter has not been reported nesting in India for the past eightyone years. *Gyps bengalensis* was the most common nesting raptor.

The ecological isolation in the congeneric, co-existing raptors is effected by the difference in their preference for perch type and height and acceptance of a social hierarchy, thereby avoiding competition for food and perch.

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TITLE **Comparative ecology of resident ducks in Keoladeo National Park, Bharatpur, Rajasthan**
STUDENT **U. Sridharan**
GUIDE **J.C. Daniel**
YEAR **1989**
UNIVERSITY **Bombay University**

Summary

Of the 23 species of ducks recorded from Keoladeo National Park, Bharatpur, four are resident ducks, namely the Lesser Whistling Teal (*Dendrocygna javanica*), Spotbill Duck (*Anas poecilorhyncha*), Cotton Teal (*Nettapus coromandelianus*) and Comb Duck (*Sarkidiornis melanotos*). No systematic studies have been carried out on the ecology of these ducks in the past in India. A comparative study on the ecology of these four species was, therefore, undertaken from January 1984 to December 1986. Population, habitat utilization, food and feeding habits, activity pattern and time budget and breeding biology of each species was studied.

The population was assessed by directly counting the birds in all the aquatic blocks using the dykes as transects. Habitat utilization of each species was studied by regularly surveying the entire aquatic area and recording the number of birds seen in each particular vegetation type or habitat. Food and feeding habits were studied by the micro-histological examination of the droppings. "Focal animal sampling method" and the "Scanning method" were adopted for studying the activity pattern. Regular observations on behaviour and periodic nest search was carried out for studying the breeding seasonality.

The population of Whistling Teal and Spotbill Duck varied from 1 to 98 and 9 to 290 respectively. In the case of Cotton Teal and Comb Ducks it fluctuated from 8 to 562 and from 1 to 101 respectively. The population of all the species was the lowest in high summer and autumn as they disperse for breeding. Significant correlation between the population of the resident ducks and the total quantum of water supplied into the Park and to the depth of water inside the Park (sic). Besides this, the population of the Spotbill Duck and Cotton Teal has a high correlation with the total biomass of floating and submerged vegetation. The latter has a high relationship with the total biomass of aquatic macrophytes and the water input. Availability of sufficient water and the resultant growth of aquatic macrophytes appear to be the major factors influencing the fluctuation of population in resident ducks. The pattern of fluctuation of population is significantly different among the four species, since they differ in habitat requirements, and food and feeding habits. However, because of the relationship in habitat preference and feeding habits, the same pattern of fluctuation was observed between the Whistling Teal and Comb Duck, and Spotbill Duck and Cotton Teal.

Although the habitat preference shows seasonal variation according to the availability of habitat, the most preferred habitat of the Whistling Teal is the rooted floating vegetation, whereas in the case of Spotbill Duck it is open water, in Cotton Teal open water and open water with floating vegetation and in Comb Duck grass patches. Niche breadth for feeding habitats of the four species is 0.451, 0.376, 0.328 and 0.349 for the Whistling Teal, Spotbill Duck, Cotton Teal and Comb Duck respectively. Cotton Teal seems to be more selective as it has the smallest niche size. All the four species of resident ducks have some overlap in their feeding habitat, the overlap between Whistling Teal and Comb Duck was the least. But between Spotbill Duck and Cotton Teal it was high since their highest preferred habitat was the same.

Even though habitat overlap does occur among the four species, competition is avoided by preferring different types of food. The seeds of *Hyphoides* formed the highest preferred food of Whistling Teal, Spotbill Duck fed mostly on *Chara* sp., Cotton Teal fed on *Hydrilla* sp. and *Spirodela* and Comb Duck fed mostly on Wheat and the seeds of *Echinochloea* sp., the former from the surrounding villages. However, seasonal variation in the food consumed was observed in all the four species.

Significant variation in the time budget was noticed among the four species. Whistling Teals and Spotbill Ducks spent 23%, 22% of the daylight hours respectively for feeding, whereas Comb Duck spent only 6%. Cotton Teal spent as much as 81% of the daylight hours. Obviously the first three species must be spending more time at night feeding. Seasonal variation in the time budget was also noticed in all the four species.

Whistling Teal, Spotbill Ducks and Comb Duck spent more time for feeding in the early hours of the day. These species have an increased resting period in the afternoon hours. Cotton teal fed throughout the day in large numbers. Spotbill Duck and Whistling Teal, Spotbill Duck and Comb Duck, Whistling Teal and Comb Duck have more or less a similar activity pattern.

The resident ducks of Keoladeo National Park breed during August-September, the rainy season. The Lesser Whistling Teal and Spotbill Duck breed during summer also. Breeding habitat varied considerably in all the four species of resident ducks. The Lesser Whistling Teal was found nesting on mounds, grassy patches and the utilized nests of Pied Myna on *Acacia* trees. Spotbill Ducks utilize mounds and grassy patches and between them mounds were used more. Cotton Teals used tree holes. Production rate was more in the case of Cotton Teals compared to all other resident ducks. No active nest of Comb Duck was seen in the Park during the study period.

Provision of water input at a single stretch during monsoon, retention of water in one block during summer, avoidance of disturbance to mounds and grassy patches, ban on tree thinning operations during breeding seasons, protection of big trees and provision of more holes on trees are suggested for the increased breeding output of resident ducks.

TITLE **Studies on the coastal birds of Mandapam and the neighbouring islands**
STUDENT **S. Balachandran**
GUIDE **Mr. J.C. Daniel**
YEAR **1990**
UNIVERSITY **Bombay University**

Summary

Mandapam and the neighbouring islands are identified as important wetlands for both resident and migrant waterbirds, especially the sand-flat preferring waders, flamingos and maritime terns.

The status of the migratory waders, in terms of arrival and departure time, duration of stay, passage and wintering migrants, summering species, their abundance and seasonal fluctuations are presented here.

The distribution of waders and other aquatic birds in different habitats, and the comparative density and diversity in different habitats are described in detail. The occurrence of certain species such as Crab Plover, Sanderling, Eastern Knot, Knot, Whimbrel, Curlew, Bartailed Godwit, Large Sand Plover, Terek Sandpiper and Grey Plover, in relatively high numbers in this area, than in other known wader habitats, was brought out well by the present study.

The species-wise annual population fluctuation in the three year study period for all the species was made through bird count data. The monthwise fluctuation for 22 species of waders and the reasons for such fluctuations are also discussed. This was possible only because the birds were densely distributed in a relatively small area.

Among the six habitats, the Pillaimadam lagoon (mud-flat with diverse microhabitats) supported a small population of large number of species. Dhanushkodi lagoon (sand-flat), supported a larger population of less number of species. Manali Island and the eastern part of Dhanushkodi have been identified as the most favoured habitats of sand-flat preferring species such as Sanderling, Knot, Eastern Knot, Curlew and Turnstone. Crab Plover, Oystercatcher appear to be confined largely to Manali Island and a few in Hare Island.

Generally a sharp decline was noted in the population of waders from 1985-86 to 1987-88. Though breeding failure and poor turnover of abundant winter visitors in the subsequent seasons could be possible reasons for such decline, the exact causes for the general decline could not be ascertained.

All the birds handled for ringing were aged under two categories: "first year" and "adult". From the proportion of young birds, the breeding success could be guessed. A direct correlation between the low proportion of young birds to the low annual population for species such as Little Stint, Curlew-Sandpiper, Grey Plover, Large Sand Plover, Terek Sandpiper was noted. But in the case of Lesser Sand Plover, a negative correlation was seen. Moult patterns for 22 species of waders were observed in detail. This is the first detailed study of this kind from Indian wintering grounds. The commencement, completion date, duration of moult, pattern of moult in the "first year" birds and variations of moult in different age classes in different populations are given. It is confirmed that birds took more time to complete their moult in the Indian wintering grounds, as already reported in other wintering grounds such as South Africa and Australia. Even then, the duration in India for species like Little Stint, Common Sandpiper and Greenshank was slightly shorter than that recorded in South Africa. However, the duration was longer when compared with that from passage site such as Waddenzee and Morocco Coasts. Arresting of the moult for more than a month was commonly found in Curlew-Sandpiper and Lesser Sand Plover.

Thousands of live waders were measured before releasing with the ring; lots of variations with the already reported measurements from different regions were found. Though slight variations could be attributed to variations in measuring live and skinned specimens, some larger variations found in some species suggested the possible occurrence of birds from other regions not collected before.

Existence of site fidelity was found in 19 species of waders by retrapping them.

Flock fidelity was also evident in species such as Bartailed Godwit and Lesser Sand Plover. The birds caught together for the first time for ringing were retrapped in later periods also.

Occurrence of some subspecies of polytypic species, found during this study, were new additions to India, e.g., two subspecies of Large Sand Plover (*crassirostris* and *leschenaultii*); three races in Lesser Sand Plover, two in "*atrifrons*" group (*schaeferi* and

atrifrons) and one in "*mongolus*" group. In Redshank, in addition to the regular "*totanus*" race; more subspecies (*eurhinus* or *robusta*) could be recognised from the biometric data.

The wintering race of Knot at Mandapam has been confirmed as *rogersi*.

Because of the rich availability of macrobenthos throughout the season at Mandapam, the passage, wintering and summering individuals utilised this habitat very well to complete their moult and to gain weight before their return journey.

As Mandapam experienced moderate climate with relatively less rainfall, the mortality due to extremities of climate and starvation was minimal during the study period. The other important feature is the absence of predators (raptors), except for Brahminy Kite which is mostly a scavenger.

Because of the occurrence of rich marine fauna and flora, the coastal habitat around Mandapam has been declared as part of the Marine National Park. As this study was conducted in this part of Marine National Park, before its declaration, the data collected during this period on the coastal birds could thus form the baseline information for any future study on related aspects of coastal ecology towards conservation and protection of this ecosystem.

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TITLE **The ecology of the Southern Crow-Pheasant *Centropus sinensis parroti* Stresemann (Aves: Cuculidae) at Point Calimere, Tamil Nadu**

STUDENT **V. Natarajan**

GUIDE **Mr. J.C. Daniel**

YEAR **1990**

UNIVERSITY **Bombay University**

Summary

The Southern Crow-pheasant *Centropus sinensis parroti* is distributed in the Indian peninsula, south of the Gangetic plain from North Gujarat, Kutch and Saurashtra east through Madhya Pradesh, Andhra and Orissa, south through Maharashtra, Mysore, Tamil Nadu, Kerala and Ceylon (Ali and Ripley 1983). Some information on general habits, nests and eggs of Southern Crow-pheasant is available (Hume 1890, Baker 1927, and Ali and Ripley 1983). However, no detailed studies have been done. In addition, the coucals or crow-pheasants, are considered to be highly destructive to eggs and nestlings of other birds. Hence, a detailed study was undertaken from August 1986 to March 1989 at Point Calimere, Thanjavur District, Tamil Nadu, on the general habits, population density, feeding ecology, general behaviour and breeding biology of the Crow-pheasant to ascertain its role in the ecosystem. The Southern Crow-pheasant is a common resident bird at Point Calimere.

Study sites were located in the Point Calimere Wildlife and Bird Sanctuary and the two adjoining villages namely Kodikkarai and Kodikkadu. More intensive studies were done in the two above mentioned villages since observations were difficult in the forest due to dense vegetation.

The biometrics, general habits namely awakening, roosting and vocalisation were studied. Regarding roosting, the tree species and roosting heights were recorded. Awakening time was correlated to sunrise. The coucal was recorded to roost in nine tree species, the most preferred being *Prosopis chilensis*, followed by *Pandanus tectorius* and *Manilkara hexandra*. Various types of calls and their significance are discussed.

Four transects representing four micro-habitat types viz., Muniappan lake (low-lying scrub), Ramarpatham (elevated scrub), Palaithoppu (disturbed scrub) and Pudukkulam (scrub with introduced species) were selected in the forest for comparative population density studies on the crow-pheasant. Density was estimated by line transect method (Emlen 1971). The density was highest in the Pudukkulam transect when compared to other transects. Based on the census, the population of crow-pheasant was estimated to be 372 individuals for the sanctuary. The abundance of possible food items like arthropods, molluscs in the four transects in relation to food abundance is discussed. Breeding bird density was estimated in the village and forest.

Behavioural activities were studied by focal animal sampling technique (Altmann 1974). The time spent on various behavioural activities such as foraging, body main-

tenance, flying, heavy cover retreat, calling are described.

The diet, feeding sites, foraging height, time spent on trees and ground and methods of feeding are described. Altogether 30 food items were recorded, all being animal matter. Two species of snails were found to constitute the major portion of the diet, eggs and nestlings of birds forming only a small portion.

The breeding season was recorded to be from November to May. Nesting and egg laying activities intensified after heavy rains. Both sexes take part in nest building, incubation and feeding the young. The nest is globular in shape with a lateral entrance, however some nests with deep cup-like structures were also recorded. Altogether 56 nest materials were identified. It was found that there was a difference in both nest materials used and vertical distribution of nests between forest and village. Nest density was found to be higher in the village than the forest. The size of eggs, clutch size, incubation period and incubation rhythm are described. The frequency of feeding trips to nestlings made by parents, growth of nestlings, fledging period and the dispersal of young and breeding success are discussed.

The study reveals that the Crow-pheasant at Point Calimere feeds on insects, snails, frogs, lizards and snakes. Comparatively, the eggs and nestlings of other birds forms less than 1% of its diet at Point Calimere. It is, therefore, evident that the Crow-pheasants at Point Calimere do not play a significant role in the nesting success of other species of birds.

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TITLE **Ecology and behaviour of the Pariah Kite *Milvus migrans govinda* (Sykes) as a problem bird at some Indian Aerodromes**
STUDENT **S.M. Satheesan**
GUIDE **Mr. J.C. Daniel**
YEAR **1990**
UNIVERSITY **Bombay University**

Summary

Birds are internationally recognized as hazard to aircraft as bird strikes are a major concern for air safety. Among the two main problem birds to aircraft in India namely the Vultures and Kites, qualitative and quantitative data on the ecology and behaviour of the Pariah Kite is lacking and hence the present study was carried out from 1980 to 1989.

All the bird-strike remnants received during 1966-89 were examined and kite-aircraft-strike incidents during 1980-89 analysed to find out the extensiveness and intensity of kites as a problem to aviation. The ecology and behaviour of the Pariah Kite mainly with reference to feeding and resting and to a lesser extent to roosting, nesting and other behavioural traits were studied and attractions of kites which make them problem birds to aircraft were investigated.

Studies were conducted at Agra during 1980-81, at Bombay during 1981-83, at Bangalore in 1983 and 1984, at Trivandrum in 1985 and 1988, at Hyderabad in 1985 and 1987 and at Madras in 1986 and 1988 inside the aerodromes as well as in the buffer zone within a radius of 25 km of the aerodrome. Comparative data from a forested area was obtained from the Gir Wildlife Sanctuary in 1983 and 1986. Whether the Kites exist independent and away from human habitations was investigated. Suggestions on measures, mainly ecological, to alleviate the Kite problem are given.

The present study revealed that Vultures (26.11%) and Kites (21.36%) were the main hazards to aviation in India. Kite strikes occurred often at lower altitudes, during flight phases within the aerodrome (90.8%) and in the forenoon hours (72.1%) with a peak around 070-0800 hours. The highest incidence of Kite strikes was in the autumn season (34.7%), the peak being in October (16%).

The food and feeding habits of the Kites were analysed in depth. The Kites at Agra roosted and nested on tall and large trees situated close to feeding sites. Population and nesting densities of the Kites at Agra were worked out. Other activities of the Kites like communal resting, bathing, sunning, drinking and playing were also studied. Personal observations as well as those made by other naturalists revealed that the Pariah Kite does not exist independent of and away from human habitation and is a commensal with man providing non-vegetarian garbage.

The present study showed that Kites struck aircraft when they were in the flight path on the ground while

resting or feeding, or in the air while flying low or soaring high on thermals. An aerodrome provided the Kites with the vast open areas, freedom from disturbance and safety (afforded by its protected nature) which they required for their daily activities. Such a favourable habitat close to a feeding site attracted the Kites to aerodromes more than the actual food available inside: the bulk of food taken by Kites was from outside the aerodromes. Direct observations as well as Kite strike analysis in India also revealed that the Kite problem was more within the aerodrome than outside.

Solving the problem of Kite-aircraft-strike-hazards involves mainly removal of all the attractions of Kites by denying food material available inside and outside the aerodrome for them, as well as harassment on a continuous basis in order to make the birds feel that the aerodrome and its vicinity is no longer a favourable habitat. Above all, organisational plans and procedures should be well designed to effectively execute the preventive and remedial measures for reducing Kite menace to aircraft.

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TITLE **Plant-animal inter-relations at Point Calimere Sanctuary**
STUDENT **P. Balsubramanian**
GUIDE **Prof. P.V. Bole**
YEAR **1990**
UNIVERSITY **Bombay University**

Summary

While working at the field station of Bombay Natural History Society at the Point Calimere Wildlife Sanctuary (Thanjavur Dist., Tamil Nadu), it became very obvious that in order to understand the functioning of ecosystem of this natural habitat, the study of plant-animal interactions was very important. Accordingly, the author started observations at this sanctuary. The observations were made on several aspects of plant-animal interactions for about a year and some interesting observations were published, a list of which is appended herewith. It was soon realized that such general observations would be superficial and lack scientific depth. It appeared necessary, therefore, to circumscribe the study to a specific topic. With the expertise available at Bombay Natural History Society and consistent with the research project objectives at the above field station, it was limited to avian frugivory.

Systematic studies of Plant-bird interactions in the Indian subcontinent seem to have started with studies by Ali (1931, 1932) followed by Kannan (1980) and Davidar (1979). Many of the above-mentioned studies mainly focused on the aspect of pollination of certain angiosperms by birds. Regarding the frugivory and seed dispersal by birds, only scattered observations have been available (e.g. Ali 1931; Hussain and Bhalla 1937 and Johnson 1982). Hence, the present study was undertaken with a view to preparing a comprehensive report on the phenomenon of fruit feeding and dispersal by birds at Point Calimere Wildlife Sanctuary.

The vegetation of the Sanctuary is of tropical dry evergreen type which is composed of over 300 species of angiosperms, of which 64 species possess fleshy fruits consumed by birds. About 140 passerine bird species were noted of which 20 species are known to consume fleshy fruits. The study was conducted to observe the interrelationships between these 64 fleshy-fruited plants, and 20 fruit-eating bird species.

The study covered two important aspects of the relationship between the plants and birds:

i. The fruiting season of plants visited by birds (bird-plants) and the population fluctuation of frugivorous birds.

ii. The characteristics of fruits eaten by birds (bird-fruits) and the gape width of the fruit-eating birds.

Of the total number (64)of fleshy-fruited plant species visited by birds, 27(42.2%) were trees, 23 (35.9%) were shrubs and 14 (21.9%) were climbers.

Three seasonal fruiting patterns were observed:

i. During monsoon and postmonsoon (October-March), 37 species produced ripe fruits.

ii. During summer and premonsoon (April-August), 13 species produced ripe fruits.

iii. 14 species produced ripe fruits throughout the year.

In general, the number of species in fruit was less during May to September and more during October to April. A peak was noticed during February to March and a dip was noticed during June.

The higher number of frugivorous bird species as well as individuals occurred between October and April. The number of frugivorous bird species as well as individuals was low between May and August.

The fruit characteristics such as colour, diameter, number of seeds were noticed. Based on colour seven classes of fruits were recognized. Red forms the dominant colour among the bird-fruits in Point Calimere followed by black. The majority of the bird-fruits measure less than 10 mm in diameter. 42 bird-fruit species have 1-2 seeds per fruit.

The gape width measurements of fruit-eating birds were also noted. The mean gape width of major frugivorous bird species was 14.3 mm and it ranges from 9.2-22.8 mm. The mean gape width of all frugivorous bird species was 10.9 mm and their gape width ranges from 4.7-22.8 mm. The distribution of gape widths of fruit-eating birds at Point Calimere is not corresponding with that of fruit diameters. The number of different fruits eaten by a bird has no relationship with its gape width size. Birds with smaller gape width visited lesser number of plant species. Birds with medium-sized gape width visited a larger number of plant species.

Among the 20 fruit-eating bird species observed, 13 species are residents, 5 species are seasonal migrants and the rest are migrants. Based on their fruit-eating behaviour three groups of fruit-eating birds were identified:

i. legitimate seed dispersers
ii. seed predators
iii. fruit thieves.

Whitebrowed Bulbul visited the largest number of plant species (63) followed by Redvented Bulbul (51). The resident bird species contributed the maximum number of visits as well as fruit removal. Migrants play a minor role.

Among the 64 bird-plant species studied, the following three plant species were visited by more than 10 bird species: i. *Salvadora persica* (15). ii. *Manilkara hexandra* (12) and iii. *Ficus tsjakela* (11).

The study shows a positive correlation between the number of plant species in fruit and the number of bird species and individuals that occurred in the study site. The observations further show that the residents, especially Whitebrowed Bulbul and Redvented Bulbul, play a dominant role in the seed dispersal in Point Calimere Sanctuary, and it is felt that these birds have a definite role to play in the ecosystem of this type of natural habitat.

A recommendation is made to enrich the sanctuary with bird-plants such as *Azadirachta indica*, *Lannea coromandelica*, *Walsura trifolia*, *Ficus microcarpa* and *Ficus tsjakela* to attract the resident birds such as Whitebrowed Bulbul and Redvented Bulbul. Plant species such as *Salvadora persica* and *Manilkara hexandra* can be planted to attract the migrant birds such as Rosy Pastor and Greyheaded Myna.

From the observations made on plant-mammal interactions, it is realized that there exists some obligatory interrelationship between *Cassia fistula* and Jackal and *Atlantia monophylla* and Shortnosed Fruit Bat. The fruit of *C. fistula* was found largely eaten and dispersed by the Jackal and to some extent by other mammals. The fruit of *A. monophylla* was found eaten only by Shortnosed Fruit Bat, and hence this plant species depends on this animal for the dispersal of its seeds. For the preservation of species such as *A. monophylla* and *C. fistula,* viable populations of Shortnosed Fruit Bat and Jackal are important. From this study it is also known that there is scope to undertake other aspects of plant-animal interaction studies, especially Plant-insect interrelations.

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TITLE	**Ecology of terrestrial birds in Keoladeo National Park, Bharatpur**
STUDENT	**T. Sundaramoorthy**
GUIDE	**Mr. J.C. Daniel**
YEAR	**1991**
UNIVERSITY	**Bombay University**

Summary

Ecological investigations on various organisms are essential to formulate a proper management plan for any protected area. Among the animals, perhaps birds are the best indicators to know the health of an ecosystem. The adjacent forest area of the wetland of the Keoladeo National Park supports 163 landbirds and 52 semi-

aquatic birds. Except raptors, no systematic studies on the ecology of these birds have been carried out so far. Therefore an ecological study, especially on the landbird community, was undertaken from January 1987 to July 1989.

For the present study, six major habitats were selected. They are mixed vegetation, kadam groves, savanna woodland, savanna woodland with thickets, grass savanna and dykes in the aquatic area.

Landbird community was studied in all the habitats except the dykes for twenty months from June 1987 to January 1989 covering seven seasons. To test the suitability of census technique for the study of landbird community, the line transect and circular plot methods with variable width were tried and the former was adopted for this study since it yielded better results. Fortnightly census was carried out in all the habitats. During census, data were collected for the estimation of species richness, abundance, species diversity and density of birds. Breeding seasonality of landbirds was studied in four habitats for thirty one months from January 1987 to July 1989. Abundance of insects was estimated in all the habitats except the dykes throughout the study period.

In all, 157 terrestrial bird species were recorded. Number of species recorded in each habitat differed considerably; 108, 87, 97, 99, 102 in mixed vegetation, kadam groves, savanna woodland, savanna woodland with thickets and grass savanna respectively. Out of 157 species, 49 were common to all the habitats, while eight were confined to mixed vegetation, three species to kadam groves, six each to savanna woodland and savanna woodland with thickets, and 24 to grass savanna. Except in grass savanna, the species richness did not show a significant seasonal fluctuation. The maximum number of bird species in a season was noticed in the mixed vegetation and the minimum in kadam groves, 67 and 33 respectively, the former was recorded during the autumn of 1987 and the latter during the summer of 1987. The maximum and minimum number of bird species and the corresponding season of occurrence in each habitat varied. During the study period three guilds were found among the habitats in their similarity in species richness, they were: i) mixed vegetation and savanna woodland with thickets ii) kadam groves and iii) grass savanna and the savanna woodland.

In all the seasons except summer 1987 and 1988, the similarity in richness among habitats differed. The mixed vegetation and savanna woodland showed closeness in most of the seasons due to the same pattern of fluctuation. The variation of bird species richness in different habitats in different seasons shows that the mixed vegetation and grass savanna richness varies from all other habitats in many seasons.

The dominant resident bird species of the park are the Roseringed Parakeet and Indian Ring Dove and, the Rosy Pastor and Lesser Whitethroat among the migrants. The most dominant bird species in mixed vegetation, kadam groves and in savanna woodland with thickets is the Roseringed Parakeet and in Savanna woodland and Grass savanna, the Indian Ring Dove.

A significant seasonal variation in the abundance of birds was recorded in all the five habitats. Maximum number of birds (1579) was in savanna woodland during spring 1988 and minimum (444) in savanna woodland with thickets during summer 1987. The abundance of birds fluctuated significantly in all the habitats. The fluctuation in each habitat depends mainly on the dominant bird species. The similarity of abundance between habitats shows two guilds: 1) the savanna woodland, savanna woodland with thickets, and kadam groves and ii) the mixed vegetation and grass savanna. In all the seasons, variation in abundance between habitats was noticed; the mixed vegetation differed considerably from all other habitats in most of the seasons.

Species diversity was calculated using Shannon-Weiner diversity index. The highest diversity was 3.44 during autumn 1987 in grass savanna and the lowest 2.27 during winter 1987 in kadam groves. Except in mixed vegetation and in savanna woodland, the seasonal fluctuation of diversity was significant. The variation of species diversity between habitats in each season varied (sic) except in summer 1988 and in winter 1988. The seasonal variation in the species richness and abundance of birds of various feeding niches were also assessed. Factors affecting the fluctuation of abundance, species richness and species diversity of each habitat are discussed.

The density was estimated based on the line transect estimation of Fourier Series Model. Total bird density and density of 17 common bird species in five different habitats and their seasonal variation were worked out. The highest density recorded in mixed vegetation and grass savanna was during winter of 1988, 1415 and 1318 birds / sq.km respectively. The highest density in other three habitats was recorded during the

spring of 1988 (1325, 1475, 1262 birds / sq. km, in kadam groves, savanna woodland and savanna woodland with thickets respectively). Among the five habitats the highest mean density, 1108 birds / sq.km, was recorded in kadam groves and the lowest 781 birds / sq.km, was in grass savanna. The savanna woodland and savanna woodland with thickets showed almost similar mean density. All the habitats showed a significant seasonal variation in the total bird density. In the total density, the savanna woodland and savanna woodland with thickets formed one guild and the remaining three habitats formed three separate guilds. The total bird density in each habitat was mainly controlled by the dominant bird species of the respective habitat.

Irrespective of habitats, the density of all the 17 bird species showed a significant seasonal variation. In all the seasons except winter 1988, the highest density was for the Roseringed Parakeet; its mean density during the study period was 912 birds / sq.km. The Indian Ring Dove and Yellow-throated Sparrow stood next to Roseringed Parakeet in the mean density. Among 17 common species, the density of Roseringed Parakeet was the highest in all the habitats except in grass savanna where the Indian Ring Dove's density was the highest, followed by the Pied Bushchat. Most of the species showed a significant variation in density between the habitats.

The breeding seasonality of terrestrial birds was studied in four different habitats, namely mixed vegetation, savanna woodland, grass savanna and two dykes between aquatic blocks. Systematic nest search was carried out twice in a month. Breeding season of terrestrial birds extended throughout the year with a major peak either in late spring or early summer and a minor peak in autumn. The number of species bred and total number of nests varied considerably during the study period. Totally 29 species with 266 nests, 51 species with 598 nests and 49 species with 360 nests were recorded in 1987, 1988 and 1989 respec-tively. Both the number of species bred and number of nests showed a significant relation with the mean temperature and humidity. An attempt is made to describe the breeding seasonality of terrestrial birds based on the available data on abiotic factors such as mean temperature, relative humidity, monthly rainfall, rainy days in each month, rain intensity and waterspread area in the wetland, and biotic components such as the abundance of insects, leaf, flower and fruit in the terrestrial plants. The main factors determining the number of species breeding in the Park are mean temperature, relative humidity, waterspread area, insect abundance and leaf abundance. The number of nests is also influenced by most of the abovementioned factors.

This study reveals the salient features of the general ecology, the role of various environmental factors on the community structure and breeding seasonality of terrestrial birds. The influence of wetland on the landbird community is also discussed. The study emphasizes the necesssity of conserving the various microhabitats to maintain higher diversity of terrestrial avifauna of the Park.

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TITLE **Some aspects of the breeding behaviour of the Lesser Florican *Sypheotides indica* (J.F. Miller) and the Bengal florican *Houbaropsis bengalensis* (Gmelin)**
STUDENT **Ravi Sankaran**
GUIDE **Mr. J.C. Daniel**
YEAR **1991**
UNIVERSITY **Bombay University**

Summary

The family Otididae, commonly known as the bustards, is represented in the Indian subcontinent by three species namely the Lesser Florican *Sypheotides indica* (J.F. Miller), Bengal Florican *Houbaropsis bengalensis* (Gmelin) and the Great Indian Bustard *Ardeotis nigriceps* (Vigors). Having been popular game birds, considerable literature on the general habits, breeding behaviour and distribution are present for the Lesser and Bengal Florican (Jerdon 1864, Hume and Marshall 1879, Baker 1921, Dharmakumarsinhji 1950, Ali and Ripley 1969, Magrath *et al.* 1985, Inskipp and Inskipp 1985, Ali *et al.* 1985, Rahmani *et al.* 1988, Narayan *et al.* 1989). Except for the detailed studies on the Bengal Florican from the wetter part of its range, Assam, (Narayan and Rosalind 1988, Narayan *et al.*

1989, Narayan 1990) the other studies were of either short durations or not detailed or both. As a result of habitat loss and excessive hunting pressures, both these species are now threatened by extinction (Goriup and Karpowicz 1981, Magrath *et al.* 1983). As a part of a larger effort to conserve these species by the Bombay Natural History Society, intensive studies on the breeding behaviour with special emphasis on courtship displays were done.

The Lesser Florican was studied at the Sailana Kharmor Sanctuary, Ratlam district in Madhya Pradesh (23° 31' N, 75° 01' E) and at the Rampura/Movalia/ Kalitalai grasslands near Dohad, Panchmahal district in Gujarat (22° 53' N, 74° 19'E). Studies on the Bengal Florican were from the driest part of its breeding range and were conducted at the Dudhwa National Park, Lakhimpur Kheri district in Uttar Pradesh (between 28° 24' N & 28° 40' N and 80° 34' E & 80° 50' E). Behavioural observations were arrived at following the focal animal sampling method (Altmann 1974). Other parameters included temperature, weather, cloud cover and intensity of rainfall. Insect abundance was assessed by the sweep count method once a week. The location and movement patterns of the birds within the territories were mapped intensively. The data on the breeding behaviour presented in this thesis was collected between June 1987 and October 1989. However, wherever necessary, data collected in both 1985 and 1986 are used. Analysis of data was done with the help of computer packages. Lotus and Systat were used to do statistical analysis and Seas was used to map territories and movement patterns of the individuals studied.

The Lesser Florican breeds in Western India during the south-west monsoon and the Bengal Florican breeds in the sub-Himalayan alluvial grasslands in the summer. The environmental factors influencing the breeding habitat of both species were examined. It was found that as a result of great inter-year variability of the southwest monsoons, the breeding habitat of the Lesser Florican showed variation between years. Distribution rather than quantum of rainfall was found to have a greater influence on grass growth. Strong correlation was obtained between grass growth and insect abundance, with insect population increasing with grass height. The Lesser Florican movements were similarly linked to the distribution of rainfall rather than the quantum. The breeding habitat of the Bengal Florican was found to be relatively more stable and the reasons for this are discussed.

The territorial behaviour of both species is described in detail, and the distribution of agonistic interactions in the breeding season was analysed. The agonistic interactions in the Lesser Florican are mainly seen in the early part of the breeding season while in the Bengal Florican it is distributed more evenly throughout the breeding season. Thorough mapping of the study areas were made and territories of males identified. The inter-year variation in the location and spacing of territories is discussed. The home range and movement patterns of the Bengal Florican within its territories were also plotted. The area occupied by three male Bengal Floricans studied ranged between 18 and 28 hectares. Inter-male distances in the Lesser Florican was on an average 366 metres with a maximum of 525 metres and a minimum of 275 metres. These distances were much greater in the Bengal Florican and ranged from a minimum of 350 metres to a maximum of 2.25 km. The territorial aspects of the Lesser and Bengal Florican breeding behaviour are discussed.

The different types of courtship behaviour in these species are described in detail. The rates of display under different weather conditions were analysed. The Lesser Florican displays at the highest rate under overcast and cloudy conditions and least so in sunny weather. Males displayed during slight drizzles, but did not do so during heavy rains. There was no variation in the display rates under different wind speeds. The variation from no-site fidelity to spot specificity in display of the Lesser Florican are analysed and discussed. Choice of display sites and the grass heights at and around the display sites are shown. The Bengal Florican was seen to display at equal rates in all weather conditions. They, however, did not display during strong rains. Performance of 75% of displays was temporarily localised to within an hour of sunrise and sunset. The influence of stimulus and triggers on the Bengal Florican displays is analysed and discussed. Location of display sites of the Bengal Florican and the variation in the sizes of these sites is analysed and discussed. The pre-copulatory behaviour of both species is described. The distribution of encounters between males and females in the breeding season is analysed. Description of nests and nesting sites and some observations on the nesting behaviour of the Lesser Florican are given.

The breeding behaviour of the Lesser Florican and the Bengal Florican are compared. Absence of breeding area fidelity in the Lesser Florican and its presence in the Bengal Florican are explained by the stability or instability in those factors that determine the breeding

environment of each species. The divergence of displays in these closely related species is shown and the similarities in the displays are pointed out. An attempt is made to explain the presence of reversed sexual dimorphism in size in both species. The dispersed lek breeding system that the Lesser and the Bengal Florican follow is discussed in relation to other polygynous species.

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TITLE **Ecology of waterbirds of Point Calimere Sanctuary with special reference to the impact of salt works**
STUDENT **Ranjit Manakadan**
GUIDE **Mr. J.C. Daniel**
YEAR **1992**
UNIVERSITY **Bombay University**

Summary

The Great Vedaranyam Swamp adjoining the Point Calimere Sanctuary (10° 18'N; 79° 51'E) is one of the largest swamps and wintering grounds for waterbirds in South India. The Great Vedaranyam Swamp could easily qualify as a 'Wetland of International Importance' as per the Ramsar Convention of 1972 by the tens of thousands of waterbirds, including some threatened species, it supports.

One of the major threats facing the Great Vedaranyam Swamp is from habitat alteration by the establishment of salt works. There is a dearth of literature on the impact of salt works on birds in India. Hence, it was felt that in-depth studies on a variety of bird species representing different guilds were necessary, especially for a country like India, where there is a rising demand for salt and the sources for which are mainly from the sea. This increased demand for salt would result in the establishment of more and more salt works as is happening in the Great Vedaranyam Swamp.

The study had the following objectives:

*Assess the status, abundance, species composition and seasonality of the waterbirds.

*Study the spatio-temporal variations in the abundance and species richness of birds between the natural habitat and the salt works.

*Relate that abundance and species richness of birds with certain physico-chemical parameters in the habitats, to understand the reasons for the variations between habitats.

*Study the populations, seasonality and habitat utilization of the Greater Flamingo *Phoenicopterus roseus* and Lesser Flamingo *Phoenicopterus minor* with special reference to salt works.

This study adopted birds as indicators of the health of the ecosystem. The study consisted of a series of census, sampling the species richness, abundance, species diversity, species events and guild structure of birds over a series of microhabitats in salt works and the natural habitat. Physico-chemical parameters such as water depth, salinity and water temperature were measured in the different microhabitats. The number of fishermen, the fish catch and workmen were also recorded, which were used as both indicators of food availability and/or disturbance.

The results are summed up as follows:

Impact of salt works on waterbirds have both negative and positive effects, depending on the species, season and site concerned. The three major factors affecting birds in salt works are salinity, water depth and human disturbance. In general, high salinity, deep water and human disturbance result in a decrease in species richness and numerical abundance of birds.

Species that are affected by salt works are ducks that feed on macrophytes, plovers and sandpipers. Birds that have benefited from salt works are the fish-eating birds, especially the Grey Pelican *Pelecanus philippensis,* Brahminy Kite *Haliastur indus,* gulls and terns. While the Lesser Flamingo has experienced loss of habitat by the establishment of salt works, the greater flamingo find reservoirs and condensers of salt works an important source of food during the monsoon and post-monsoon period.

In general, salt works on the east coast of India are less detrimental to birds, as three months of the off-season of salt works on the east coast coincides with the arrival of migrants to the Indian subcontinent. On the west coast, the bird season coincides with the peak salt

season. Industrial salt works, which have about 10% of the area under crystallizers, are less detrimental to birds than edible salt works, which have about 90% under crystallizers.

The following recommendations are given:

*Prevent total draining of reservoirs and condensers during the post monsoon period.

*Dilute the bittern (waste product) either with fresh or sea water before discharging it into the Great Vedaranyam Swamp.

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TITLE **Ecology, distribution and conservation of the Bengal florican *Houbaropsis bengalensis* (Gmelin)**
STUDENT **Goutam Narayan**
GUIDE **Mr. J.C. Daniel**
YEAR **1992**
UNIVERSITY **Bombay University**

Summary

The Bengal Florican *Houbaropsis bengalensis* is perhaps the rarest member of the Otididae family. Of the two subspecies, *H.b. bengalensis* (Gmelin 1789) and *H.b. blandini* Delacour (1928), the former has an estimated world population of 350 to 400, of which, 250 to 300 are found in India; the rest are in Nepal. It is probably extinct in Bangladesh. The status of *H.b. blandini*, which was first described from Kampuchea, is unknown.

The ecology of the Bengal Florican was studied at the Manas Wildlife Sanctuary (90°45' to 91°25'E and 26°40' to 26°50'N). Located at the foothills of the Bhutan Himalayas in Barpeta, Kokrajhar and Nalbari districts of Assam. Additionally, most areas in West Bengal, Assam and Uttar Pradesh currently holding Bengal Florican populations were surveyed. The data presented in this thesis was collected between January 1986 and June 1989.

Behavioural studies were made using the focal animal sampling method. Influence of environmental factors such as temperature, wind, cloud cover and rainfall on the Bengal Florican's behaviour and its habitat was studied. Habitat studies were done through ground cover frequency and sampling methods, recording grass height, species composition, vegetation density and phenology. Insect composition and abundance were measured using the sweep count method. The locations of the male territories were mapped. The behavior of the florican towards other birds and animals was recorded. A meteorological station was established in the study area. Data were analysed using personal computer packages such as Dbase III, Lotus 123 and Systat.

The morphology of the Bengal Florican is described in detail and its taxonomic affinity with other bustards is discussed.

The former distribution of the Bengal Florican was investigated through a literature review. In India, the Bengal Florican was found in grasslands along the Himalayan foothills and in the Brahmaputra valley. Their range extended from the *kader* of river Ganges in the west to the *churs* of the river Brahmaputra up to the foot of the Mishmi hills in the east. However, it is now locally extinct through most of its former ranges and survives in disjunct pockets in Uttar Pradesh, West Bengal, Assam and Arunachal Pradesh. The only known sites where the Bengal Florican breeds today in India are Manas Wildlife Sanctuary (approximate population of 80 birds), Orang Wildlife Sanctuary (c. 35), Kaziranga National Park (c. 30), Pabitora (4 to 6) in Assam. In West Bengal, its status is far more precarious with Jaldapara Wildlife Sanctuary (c. 10 birds), Sahabad-Sayedabad and Chapra tea-estates (2-3 birds each) being the only areas where the florican was seen. Dudhwa Tiger Reserve (c. 40-45 birds) is perhaps the sole area where the florican breeds in Uttar Pradesh. About 20 birds are reported to be present in the D'Ering Memorial (Lali) Wildlife Sanctuary in Arunachal Pradesh.

The annual cycle of changes in the florican habitat at Manas was studied; the composition, height, density and phenology were quantified. The floricans preferred flat, moist, well drained and almost treeless grasslands. Their habitat was dominated by densely growing and comparatively shorter species of grass and shrubs such as *Imperata cylindrica, Saccharum narenga, Grewia sapida and Sonchus arvensis* which measured from 25 to 50 cm in the beginning of the breeding season. The

grasses reached a height of about 75 to 175 cm towards the end of the season. In Manas, the new grass growth began after burning in December or January and its growth was controlled by type of soil and abundance of other shrubs. The seasonal and long term changes in the grasslands with particular reference to the florican territories has been discussed. A significant finding was that the male florican established territory only in those areas where the previous year's vegetation has either been burnt or cleared. The role of ungulates in creating short grass patches through grazing or trampling and its significance to the florican habitat has been discussed.

The Bengal Florican was studied mainly during the breeding season. Its behaviour was broadly classified into two categories: a) those having reproductive functions, b) all other activities such as foraging, preening, etc.

The foraging and feeding habits are described. The Bengal Florican was found to be omnivorous and its diet included fruits of shrubs such as *Grewia sapida* and seeds as well as succulent shoots of sedge and grass like *Imperata cylindrica.* They also fed on grasshoppers, locusts, moths, beetles and other small insects. Rarely, they caught and ate small vertebrates too.

Other behaviour such as vocalization, modes of locomotion, reaction to danger, maintenance activities and roosting etc. were studied and are described in detail. The daily activity pattern of the male florican has also been presented.

The breeding behaviour of the Bengal Florican is described in detail. The male floricans were territorial for about four months between early February and late May at Manas. The various displays of the male florican have been described and presented with the help of ethograms. The agonistic interactions are described and seasonal variations within these have been presented. Two main advertisement displays are described and quantified. A courtship display that the males perform only in the presence of a female has been discussed.

Three nests were found during the study at Manas Wildlife Sanctuary. The nesting period, clutch size, location and microhabitat of the nest sites and other details are presented. The behaviour of the female at the nest and with young are described. The inter-specific interactions of the Bengal Florican with the birds and mammals of its habitat are described.

The conservation perspective of the Bengal Florican has been presented along with the basic requirements for its survival and factors responsible for its decline. The man-made alterations and destruction of grasslands are perceived as the greatest threat to the bird. Conversion of grasslands into cultivations, grazing lands or settlements outside the protected areas has succeeded in eliminating the bird from a large part of its range. Inside protected areas, plantation of trees, incorrect grass burning, harvesting or harrowing regimes, and other improper management practices are the major problems. Throughout its range, hunting in the breeding season, when the floricans are particularly prominent and vulnerable, contributed to its decline. Now the only viable populations remain in those areas that have been accorded proper protection as Wildlife Sanctuaries or National Parks.

The dispersal patterns of the existing Bengal Florican populations are commented upon. An attempt has been made to discuss if the existing populations are isolated or there is some gene flow between them. Based on the available data, a long term conservation strategy for continued survival of the species, recolonisation and expansion of its breeding habitat has been formulated.

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TITLE **The comparative ecology of the Pheasant-tailed and Bronzewinged Jacanas in Keoladeo National Park, Bharatpur, Rajasthan**

STUDENT **N.K. Ramachandran**

GUIDE **Dr. V.S. Vijayan**

YEAR **1993**

UNIVERSITY **Bombay University**

Summary

Jacanidae, a circumtropical family of shorebirds, that inhabits freshwater swamps and marshes, is represented in the Indian subcontinent by two species, namely the Pheasant-tailed Jacana *Hydrophasianus chirurgus* and Bronzewinged Jacana *Metopidius indicus.* Although these species are reported to be polyandrous, very little is known about the different facets of their

ecology. Therefore, a systematic study was carried out from 1986 to 1988 covering various aspects of their ecology namely, population and distribution, habitat selection, association, activity pattern, time budget and breeding biology, and an attempt has been made to use these species as indicators of the habitat quality.

The population was assessed counting the birds directly in all the aquatic blocks, using the dykes as transects. Data on their microhabitat selection and preference were collected by regularly surveying the entire aquatic area in different times of the day, recording the number of Jacanas and habitat along with their activity, and the number, identity and activity of the associated avian species. The activity of Jacanas was recorded for assessing the relation between microhabitat requirement and activity. Data collected on the number and activity of the species associated with the Jacanas were used to study and characterise their association with other avian species. Records on the activity of the associated species helped in understanding the nature and intensity of interaction. The role of habitat in such interaction was also ascertained. The quality of the habitat was assessed in terms of macrophyte and macroinvertebrate abundance by sampling these from the feeding as well as non-feeding areas. Macrophyte was sampled using chartered quadrat and macroinvertebrate (sic) by modified Wisconsin trap. Activity pattern and time budget of both the species were recorded by focal animal sampling. Breeding was studied by conducting regular nest survey inside the Park during the breeding season.

The population of both the species of Jacanas showed seasonal variation. It usually shot up during monsoon and winter. The highest number of the Pheasant-tailed was recorded during 1988, whereas in the Bronzewinged it was in 1986. During the study period, both the species of Jacanas did not occur together in good numbers and this may be due to their differential requirements of habitats. It is noticed that the climatic perturbation like drought negatively affects their breeding and hence, rainfall in the study area as well as in the surroundings plays a decisive role in maintaining their population inside the Park. The availability of better habitats around the Park also determines the population inside the Park. Both the species of Jacanas when present inside the Park showed certain pattern of distribution which has correspondence with the distribution of certain macroinvertebrate taxa.

Both the species of Jacanas showed non-random negative association with other avian species which was effected through special preference for certain habitats and spatial segregation when their habitat requirements coincided.

The activity pattern of the Pheasant-tailed Jacana varied seasonally, whereas that of the Bronzewinged Jacana was more or less similar and consistent. In the latter, each feeding bout was invariably followed by a maintenance bout. The inconsistency in the activity pattern of the Pheasant-tailed is attributed to the necessity of responding to certain non-stochastic uncertainties such as predators and conspecific intruders. The time budget of both the Jacanas showed that they set aside a considerable time of the day for feeding followed by maintenance activities, although it varied seasonally.

The Pheasant-tailed as well as Bronzewinged Jacanas actively selected their habitats. The number of habitats utilized by each species varied seasonally and annually. The highest preferred habitat of the Pheasant-tailed in all seasons except in winter was submerged vegetation, followed by submerged with floating vegetation. During winter it preferred habitat formed by recrudescent grass patch. Preferred habitats of the Bronzewinged were submerged vegetation *Ipomoea* patch, or *Eichhornia* patch or the combination of any of these. A combination of these habitats placed abutting one another constitutes the habitat of the Bronzewinged Jacana. Based on the intensity of usage, the habitat of the Pheasant-tailed and Bronzewinged Jacanas could be clustered into five and six groups respectively. Preening followed by bath in both the species of Jacanas was performed on floating platform formed of vegetation such as *Ipomoea aquatica*, *Paspalum distichum*, *Nymphaea nouchali* or *Eichhornia crassipes*.

Five ecological categories of aquatic vegetation, namely emergent, floating vegetation with large leaves, floating vegetation with small leaves, submerged vegetation and grass were recognized as having some bearing on the habitat selection of Jacanas. If there was no vegetation, that area was considered as open water. Significant seasonal variation in the utilization of all vegetational categories except in floating vegetation with large leaves for Bronzewinged and emergent for Pheasant-tailed Jacana was noticed. Since the feeding and non-feeding areas of both species showed significant variation in almost all the vegetational

categories, it has to be assumed that the proportional representation of different vegetational categories rather than the simple presence or absence or their independent abundance matter to the bird when it is selecting the habitat.

Water depth in the feeding areas of both the species also showed seasonal variation.

The habitat niche width of the Pheasant-tailed Jacana was the highest (0.20) and lowest (0.08) during the monsoon of 1986 and 1987 respectively, and it showed a negative slope through the seasons indicating the deteriorating habitat quality caused mainly by the consecutive droughts. The highest value of niche width for the Bronzewinged Jacana was in the winter of 1986.

There was a significant seasonal variation in the abundance of different macroinvertebrate taxa in the feeding area of both the species of Jacanas. These taxa either by their combined total, or individually, influence the habitat selection of both the Jacanas.

The Bronzewinged Jacana bred in good numbers during 1986, and Pheasant-tailed Jacana did so in 1988 while both the species did not breed during 1987 because of the failure of monsoon, and low water storage inside the Park. The breeding season in the Pheasant-tailed Jacana was from August to September. The major abiotic factors determining the breeding season seem to be the timing and intensity of the south-west monsoon, and the availability of water inside the Park. The important abiotic factors determining the breeding season are availability of food and habitats.

A total of 42 pairs of the Bronzewinged Jacana bred inside the Park during 1986. The adult to immature ratio in the Bronzewinged Jacana was 36:22 at the end of its breeding season (September). During 1988 only three pairs of this species bred inside the Park, and the species underwent complete, simultaneous moult after breeding.

During 1988, 40 nests of the Pheasant-tailed Jacana were recorded. The clutch size of this species varied from one to five. Clutch size of four had the highest frequency distribution (0.62) followed by three (0.17). The Bronzewinged Jacana was not polyandrous during 1986, which appears to be due to the non-availability of long stretches of its required habitat in the study area.

The preference for particular habitat by each species, and the fluctuation of population and breeding density according to the changes in the habitat show that the habitat quality could be assessed by monitoring the population and breeding density of the Pheasant-tailed and Bronzewinged Jacanas. In other words, these two species could be considered as indicators of the habitat quality.

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TITLE **Ecology and conservation of the Great Pied Hornbill (*Buceros bicornis*) in the Western Ghats of southern India**
STUDENT **Ragupathy Kannan**
GUIDE **Dr. Douglas James**
YEAR **1994**
UNIVERSITY **Arkansas University, USA**

Summary

Fruiting phenology of principal fruits consumed by the endangered Great Pied Hornbill (*Buceros bicornis*) were monitored in a wet forest habitat in southern India for two years. Lipid-rich fruits, produced by deep forest trees of the family Lauraceae, Myristicaceae, and Burseraceae, were highly seasonal in their availability, and their production in the hot season coincided with the breeding season of the hornbill. These fruits showed a staggered pattern of availability. Sugary fruits, represented mainly by several species of *Ficus,* were available year round. *Ficus* was seasonal, fruited during the times of low resource availability, was heavily preferred by Hornbills and other avian frugivores and thus played a keystone role in the maintenance of the frugivorous community.

Nesting and foraging habitat of the endangered Great Pied Hornbill (*Buceros bicornis*) was quantified in a wet forest habitat in the Western Ghats of southern India. Twenty-four nest sites and 20 foraging sites on fig trees were characterized for a set of factors which were then compared with the same factors in randomly chosen sites. The factors which were significantly different in the chosen sites reflected the size and age of the tree. The results indicate the overwhelming

importance of the native forests with large sized trees for the nesting and foraging of the Hornbill.

Great Pied Hornbills are monogamous and territorial species. During courtship feeding, male and female grappled with each other with bills locked and emitting clapping sounds. This kind of grappling behaviour has not been reported from anywhere else.

The nesting cavity was on a lofty *Alseodaphne semecarpifolia* (Lauraceae) tree in deep evergreen forest. The cavity entrance was nearly circular in shape. Twenty three other nests were located in the Anaimalai Hills between 1991 and 1992. The clutch size in the present study was more than one egg. In both the 1991-92 and 92-93 seasons, the birds were first seen making short visits to the nest in early December, more than two months before the female bird became sealed in the cavity. The birds are exceptionally shy during such visits and may abandon a nest-site if disturbed then. The bird exclusively used its own excreta as cementing material, with no mud deliveries from the male.

Chemical analysis of the broken chunk of cavity entrance plaster that fell to the midden showed that the plaster closely matched the chemical composition of chicken and cattle faecal material, and was very different from the nitrogen, total ash, and organic content of tropical soil. This showed that the original plaster used to seal the cavity opening also was wholly faecal matter without an admixture of the soil reported in the past. At least 19 species of fruits and 7 species of vertebrates were delivered by the parent Hornbills to the nest inmate(s).

Active management and protection of fig tree populations and increased protection of active and traditionally used nest sites by banning or controlling honey collection, are two of the important issues discussed. Future research is encouraged on the management of existing nest cavities, experimentation with artificial cavities and compiling accurate data on the current status and distribution of the species within its historic range.

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TITLE **Sexual conflicts and polyandry in Bronze-winged Jacanas**
STUDENT **Stuart Butchart**
GUIDE **Nick Davies**
YEAR **1994**
UNIVERSITY **Cambridge**

Summary

I studied a population of 40-60 Bronze-winged Jacanas *Metopidius indicus* for three breeding seasons during 1995-1997, at Vembanur Lake in southern India. Jacanas were sex-role reversed: females were heavier and behaviourally dominant to males. Males carried out all the incubation and brooding of the chicks, and as a result the potential reproductive rate of females was four times greater than that of males, indicating that strongly reversed sexual selection probably operates in this species. About 60% of resident females were monogamous and 40% were polyandrous, defending and mating with up to four males. Over 90% of clutches found during the laying period were predated before hatching. Experiments with artificial clutches of plasticene eggs suggested that rodents (probably Indian Mole Rat, Brown Rat or Black Rat) and birds (possibly Purple or Night Herons) were responsible.

Jacana territories were exclusive within the sexes, and female territories encompassed 1-4 male territories. The breeding density was limited by both habitat availability and competition for territories. Territory vacancies created by removal experiments were filled quickly either by floaters, neighbours, or male co-mates which expanded their territories. Changes in male territories had a significantly greater impact on the size and location of female territories than vice versa. Female dispersion was therefore influenced by the dispersion of males. However, males also played an active part in mate changes through occasional territory adjustments, and sexual interactions with females. Male territory size did not seem to be determined by the dispersion of resources, but behaviour. Males defended smaller territories, so the degree of polyandry depended on both male and female territory sizes. Males may have attempted to maximize territory size in order to minimize harem size, because male reproductive success probably declines with harem size.

Sperm competition in polyandrous jacana was intense because females copulated with multiple mates before laying each clutch. The patterns of male- and

female-initiated sex events indicated that sexual conflicts occur over the timing of copulations. Females may have given copulations to clutch receivers in order to assure them of their paternity, to ensure their parental care (particularly in polyandrous groups), and to non-receivers in order to retain them in their harem. However, copulations with non-receivers may be less important than with receivers, because the costs of receivers rejecting clutches may be greater than the costs of losing males from the harem.

Conventional paternity guards such as male-guarding and frequent copulations may be ineffective in jacanas. Males may use an alternative strategy by giving a call, termed the "yell", to compete for sexual access to their mate. Males yelled at higher rates in larger harems, when the female was further from the yeller or on a co-mate's territory. Nearly half of all yells were given at mating platforms where all copulations occurred. Males which received the clutch yelled at higher rates than non-receivers during the laying period, and at lower rates during the incubation and chick-care periods. Yells attracted the female when she was far from the yeller or with a co-mate. When the yell of a polyandrous male was broadcast from a loudspeaker in his territory, the female was more likely to fly to his territory during playback than during control periods. Within polyandrous groups the males which yelled at highest rates received the most copulations. Intrusions by females, but not males, increased during yell playbacks, and tended to be more frequent on the territories of males with high yell rates, so females may be effectively blackmailed into responding to their mate's yells because yells may attract female intruders.

I discuss the relevance of these results to ideas about the evolution of sex-role reversal and polyandry in jacanas, and conclude that high rates of clutch loss and high levels of competition for territories may have been important factors favouring the evolution of this breeding system.

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TITLE	**Ornithology of the Eastern Ghats**
STUDENT	**Bharat Bhushan**
GUIDE	**Mr. J.C. Daniel**
YEAR	**1994**
UNIVERSITY	**Bombay University**

Summary

This study documents the ornithology of the Eastern Ghats in south Andhra Pradesh with special reference to the status of the rare and endemic Jerdon's or Double-banded Courser *Rhinoptilus bitorquatus* (Blyth) (Class Aves : Glareolidae).

This presentation of the avifauna consequently aims at identifying areas for conservation in this important biogeographic region, based on results detailing avian species diversity and presence of the rare Jerdon's Courser.

The Eastern Ghats are important because of their influence on peninsular climate and biotic distributions. They support the last tracts of remnant humid forest in the peninsula. Various studies have pointed out the importance of studying the bird populations of the Eastern Ghats. The earlier avifaunal listings including detailed ornithological surveys like the Vernay (1929-30) and Sálim Ali's Hyderabad (1931-32) surveys have been carried out sixty years ago.

The study area in the Eastern Ghats complex of south Andhra Pradesh comprises the Velikonda, Seshachalam, Nagari, Lankamalai, Nallamalai and Erramalai hill ranges. Main study areas are the Sri Venkateswara National Park, Palakonda ranges, at Tirupati (Chittoor District) and the Sri Lankamalleswara Wildlife Sanctuary, Lankamalai hills, at Siddavattam (Cuddapah district).

Aimed at covering all representative areas in south Andhra Pradesh, the study complements the results of earlier studies, most of which were confined to Visakhapatnam and adjoining areas of north-eastern Andhra Pradesh.

The Jerdon's Courser surveys were conducted in the Godavari and Pennar river valleys along with the Eastern Ghats in Andhra Pradesh. Detailed surveys in reported areas and intensive studies in confirmed locations formed the twin phases of the Courser studies.

The Jerdon's Courser was considered to be extinct or thought to be so, owing to the lack of records since 1900. An earlier phase of this study rediscovered the

Jerdon's Courser in the Lankamalai forests in the Cuddapah district of Andhra Pradesh. The present status of the bird is poorly known but is considered to be highly endangered because of its limited distribution.

The objectives of this study were - (1) To study avian populations in the Eastern Ghats of south Andhra Pradesh on parameters of their habitat selection, migration, species composition and distribution and impact of encroachments by agriculture on natural habitat, (2) To study the distribution of the endemic Jerdon's Courser and status of its habitat, and (3) To recommend conservation measures wherever (a) avian species diversity is high, and (b) Jerdon's Courser reports are confirmed.

This study also discusses avian biogeography in peninsular hills in relation to Sunder Lal Hora's Satpura Hypothesis and Sálim Ali's Satpura (Ornitho-geographical) Highway Hypothesis. Humayun Abdulali and Dillon Ripley in their studies have indicated that the Eastern Ghats must also have been an important link between the peninsula and the eastern Himalayas and a suitable habitat for relictual Himalayan biota.

Primary data sources were based on extensive field surveys in the Eastern Ghats. The field surveys included mist-netting and other capture methods to document avian biometrics wherever necessary. The netting operations helped document data on bird migration, distribution patterns, habitat selection and species composition. Secondary data sources were from documenting biometrics from bird collections housed in various natural history museums. Literature searches focused on earlier surveys in the Eastern Ghats, other peninsular hills and in Eastern Himalayas to discuss ornithogeography in the subcontinent.

Avian biogeography was studied by recording the geographic determinants and comparing checklists with relevant studies of the various regions *vis-a-vis* the Satpura Hypothesis. Checklists and results from intensive field studies were compared on a temporal basis for different biomes, like wetlands, forests and agricultural zones.

This study examined the present position of the Jerdon's Courser in the known regions of its distribution in order to assess status as well as evaluate its habitat. This attempt was in the form of intensive surveys in the Velikonda, Palakonda and Lankamalai hills of south Andhra Pradesh.

Patterns of bird distribution in the Eastern Ghats were studied with respect to physical barriers and mobility, and environmental requirements that could limit size and discontinuity of range in species. Key flyways of bird migration in the Eastern Ghats were recorded.

Commonness and rarity of birds in the Eastern Ghats were recorded and also subsequently analysed in relation to changes in land use. Habitat utilisation by local bird communities and their distinctiveness were recorded.

The study assessed human impact on forest cover in the area. Consequently, the study identified areas for conservation in the Eastern Ghats based on results detailing local avian species diversity.

Presence or absence of a species has been studied under variables of differing study areas, habitats, forest-types and seasons. This study assessed the status of the habitat on the basis of the extent of degradation of vegetation and habitat fragmentation.

The working hypothesis that significant man-related changes in the physical and biotic environment are affecting the distribution of birdlife was examined. Much of the Eastern Ghats has escaped sustained pressure from deforestation in south Andhra Pradesh unlike the northern regions. Some forests in the northern districts have been lost to 'development'. The southern districts of Andhra Pradesh currently can still boast of regions about 1000 sq. km. or more — at least two of more than 3000 sq. km. of intact forests except for minor forest produce extraction.

However, the Eastern Ghats in South Andhra Pradesh is currently under pressure and the impact is already visible. Some plains and foothill forests were lost even during the study period. Irrigation and other development projects have also contributed to the degradation and loss of forest habitat.

The Eastern Ghats in south Andhra Pradesh are a vital conservation zone. Potential for demarcating new protected areas on the basis of avian diversity is excellent. The forests in these tracts are largely intact and human impact levels are minimal.

Local avian distribution patterns were found to be influenced by habitat variation. Conservation priorities were identified on the basis of detailed knowledge of the habitat distribution and species diversity for each particular region. This in turn helped identify areas with high habitat and bird-species diversity. Target species like the Jerdon's Courser needed specific recommendations for their distribution range.

Ideal areas for conservation would be areas with high habitat diversity and high bird diversity unless there is need to conserve any particular endangered target

species, e.g. Jerdon's Courser, in a specific habitat.

The focus on the Jerdon's Courser in this study has been crucial for achieving and promoting conservation action in most of the districts of southern Andhra Pradesh. These regions have tremendous potential towards expanding the network of protected areas.

Based on recommendations made during the study, the Andhra Pradesh Forest Department has demarcated and notified the Sri Venkateshwara National Park (approx. area 500 sq km) and the Velikonda Wildlife Sanctuary (area proposed approx. 1300 sq.km.)

Recommendations in this thesis on management of these protected areas are based on parameters of 1. Destruction of forest cover, 2. Minor forest produce and timber extraction, 3. Encroachment by cultivation, 4. Freshwater resource management, 5. Industrial growth, 6. Soil erosion, 7. Growth of local villages. 8. Smuggling of red sanders and poaching of wildlife.

Recommendations for additional protected areas are made on the basis of 1. Background data from the Vernay and Sálim Ali's surveys, BNHS Endangered Species and Bird Migration Projects, and local birdwatchers in relation to this study, 2. Results from this study detailing avian species diversity and habitat types, and 3. Regional forest department working-plans and actual status of forest-cover in particular areas.

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TITLE **Feeding and breeding biology of Grey Pelican at Nelapattu Bird Sanctuary in Andhra Pradesh**
STUDENT **V. Nagulu**
SUPERVISOR **Dr. J.V. Ramana Rao**
YEAR **1994**
UNIVERSITY **Osmania University**

Summary

The present work is an effort to assess current status and to provide data basic to efforts to improve the current status of the Grey Pelican. Of the several reported breeding places, the one at Nelapattu seems to be the most popular and successful. The habitat features described are contrasted with those of other breeding places. The physiography and use pattern is discussed. The arrival of the birds seem to follow repeatable time schedule. By the time Grey Pelicans arrive, other occupants such as the Openbilled Storks, and White Ibises are already established. Others such as Cormorant, Grey Herons and Night Herons soon join and the Grey Pelican lives in harmony with them all. The Grey Pelicans are monogamous and pairing occurs at the breeding site, about a week after arrival during which period they are all nesting. Nest building activity is shared by both male and female and is mostly done between 0700 and 0900 hours. Whenever the male is away collecting material from nearby scrub, the female patiently awaits to receive and arrange the material subsequently. Being gregarious by nature, the pelicans construct their nests in a circular fashion, closely adjoining so that when seated on individual nests, the birds almost touch each other. 5-7 days after commencement of nest building, it is presumed that the first egg is laid. The clutch of 3 is completed in about 7 days and with the arrival of the third egg, mating activity ceases. The period of incubation for hatching each egg is about 30 days. The young are born naked and red and the plumage appears from the third day onwards first as white down, intensified after 10-12 days.

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TITLE **Ecology and biology of the Indian Peafowl *Pavo cristatus* in the Aligarh region**
STUDENT **Shahla Yasmin**
GUIDE **Dr. H.S.A. Yahya**
YEAR **1995**
UNIVERSITY **Aligarh Muslim University**

Summary

Of the 49 species of pheasants, 17 are found in India. Most of the pheasant species have a restricted distribution and are very sensitive to habitat destruction. Indian Peafowl *Pavo cristatus* appears to have adapted to the habitats modified by man, is widely distributed and in several places, it occurs in close association with man. A detailed study on the ecology of this species would reveal the factors leading to successful colonization of man-altered landscapes, its present status and the limiting factors controlling its population. The basic information on these aspects can help in the management of this species.

The present study was undertaken to gather baseline information on the ecology and biology of Indian Peafowl in an agro-ecosystem. The data were collected on following aspects: population dynamics, habitat utilization pattern, vocalization and courtship behaviour, food and feeding habits and breeding biology.

Population of peafowl was estimated by total count on roosts. Habitat utilization pattern was studied by direct sightings of both marked and unmarked individuals in different habitats. Habitat use in relation to availability was determined with the help of compositional analysis. Home ranges of eight marked individuals were determined by minimum convex polygon method (MCP). Each and every call was recorded, while studying the activity budget. Thus, both seasonal and hourly variation in the vocalization pattern could be determined. Food and feeding habits were studied by direct observations and micro-histological examination of the droppings. Courtship behaviour was studied by focal animal sampling method.

Total count was the most appropriate method for sampling peafowl population in a small area like Aligarh Fort. There was a higher proportion of male to female and the exponential rate of increase 'r' calculated during 1989-1994 showed a declining trend. Even though, the value of decrease in population size is low and the population may be considered stable at present, the age structure shows the presence of higher proportion of older than younger individuals. Such a population can decrease very fast if the prevailing conditions continue, as the older individuals die on reaching the physiological life span. The density of peafowl in the study area was 1.2-1.3 individuals per hectare.

When the total sightings of the individuals was considered, the habitats were preferred in the following order: scrub > open barren land > crop fields > plantation. When the MCP ranges of the marked individuals were considered, the order was: scrub > open barren land > plantation > crop fields, but, when the proportion of locations of the individuals were considered in their respective home ranges, then, the order of habitat preference changed: scrub > crop fields > open barren land > plantation. Thus, the bias in the number of sightings in the open barren land could be because it was the transition zone between the scrub and crop fields. There was seasonal variation in the use of different habitats.

Analysis of microhabitat variables revealed that tall and sturdy trees, shrubs of all heights and proximity to crop fields and water seem to be important cues used by peafowl for habitat selection. The use of trees and shrubs also showed seasonal and hourly variation. Trees were used significantly more during summer and monsoon and significantly more during the morning and noon hours. Shrubs were used significantly more during summer and in the noon and afternoon hours.

Among the roosting trees, *Albizzia lebbeck* and *Dalbergia sissoo* were the preferred species. These were the trees of greatest height in the study area. A comparison of used and unused trees showed that, trees selected for roosting were greater in height, had larger girth and greater height of first branch from the ground than the unused tees. There was seasonal variation in the use of different tree species. *Dalbergia sissoo* was used more than expected during winter, *Holoptelia integrifolia* was used more than expected during summer, while there was no major seasonal variation in the use of *Azadirachta indica*.

Vocalization pattern showed seasonal variation and variation seems to be related to breeding activity. There was intensive calling activity during the breeding season, less during the non-breeding season. Moreover, calls were more redundant during the breeding season. There was diurnal variation in calling activity with intense calling during the morning and evening hours. Percent cloud cover and temperature were positively correlated, while rain and wind were insignificantly correlated to the call output. About eleven call types could be distinguished, but, there was gradation of one call type into another.

Feeding habits were studied by direct observations and droppings analysis. Both the methods revealed that peafowl feed primarily on plant matter. Out of 1960 observations, 55.36% of peafowl were recorded feeding on wild herbs and 44.64% on crop plants. In the wild the most favoured species were *Dichanthium annulatum*, *Pluchea lanceolata, Achyranthes aspera* and *Panicum antidotale*. There was insignificant correlation between the abundance of wild herbs and their utilization in most of the months suggesting that peafowl feed selectively on different plant species, except during May, August and November, when the utilization of wild herbs were in relation to their availability. Among the crop plants, the most favoured species were *Brassica campestris* and *Triticum aestivum.*

Though, males utilized all the available habitats, distribution of display sites was clumped and not evenly distributed in the entire habitat. Males mostly selected display sites in scrub, which was relatively undisturbed area as compared to other habitat types. The topography of scrub probably facilitated efficient transmission of vocal and visual signals. Display rate (proportion of time spent in displaying in females' absence), call length (proportion of calls having notes greater than five) and length were found to affect the male mating success.

Nesting success of peahens in relation to habitat characteristics could not be studied in detail because of human interference. The local authorities cleared away the *Capparis* bushes and grass cover during monsoon, which formed protective cover for nests. This led to exposed area and lesser concealment of nests. Moreover, the local people deliberately carried away the eggs, as they found peafowl eggs great delicacies.

The limiting factor for the population under study was probably the availability of nesting cover. Thus, peafowl have adapted to man-altered environment, their population can decline rapidly due to severe habitat destruction. In other areas also, peafowl population could decline due to habitat destruction or hunting. Hunting pressure could even lead to local extinction. At present, peafowl do not require to be conserved urgently, because, in several parts of India, it is common and abundant. But, I suggest that peafowl population can be managed by manipulating the ground cover, which in turn would regulate the reproductive output of the species.

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TITLE	**Ecology of sympatric woodpecker species of Western Ghats, India**
STUDENT	**V. Santharam**
SUPERVISOR	**Dr. Priya Davidar**
YEAR	**1995**
UNIVERSITY	**Pondicherry University**

Summary

The study was conducted at the Peechi-Vazhani Wildlife Sanctuary (10°28'N-10°40'N latitude and 70°17'E-76°29'E longitude) in the Trichur Forest Division of Kerala state and located in the Southern Western Ghats south of the Palghat Gap.

Woodpeckers may be considered as model organisms to test the competitive exclusion theory, as several species, varying in size and level of specialization, typically co-exist in forest habitats, both in temperate and tropical regions. Studies in the temperate regions have shown many ways that sympatric woodpeckers differ in foraging and nesting requirements. These include differences in foraging behaviors, use of different micro- and macrohabitats and use of resources at different times. Woodpeckers are important components of forest communities and play a vital role in forest ecosystems. Being insectivorous, they help in controlling bark insects directly by feeding on them and indirectly by altering the microclimatic condition in tree barks. Forestry practices such as selective logging can be detrimental to woodpecker populations. Removal of dead trees or snags

and large trees with decaying trunks or dead branches reduce nesting and foraging sites for woodpeckers.

Therefore, there is an urgent need to understand the ecology of tropical woodpeckers: their habitat need in forms of foraging and nesting, their interaction with one another and other hole-nesters, and their population densities, in order to save them and their habitats.

This study was initiated with the following objectives at the Peechi-Vazhani Wildlife Sanctuary, Kerala between 1991 and 1993:

1. To determine the resource utilization by sympatric woodpecker species to see if they differed in their foraging behaviour, foraging habitats, nest sites, and nesting habitats.

2. To determine the densities of the various species in natural forests and manmade plantations.

3. To draw up strategies for conservation and management of woodpeckers and their habitats.

In total, 27 diurnal cavity nesting bird species including eight woodpecker species were recorded in all the sites combined. Together with six owl species and the occasional Malabar Grey Hornbill (*Tockus griseus*), cavity nesters constituted about 30% of the total resident avifauna of the study sites in forest habitats. In 1991-92, a total of 21 species of cavity nesters including seven species of woodpeckers were seen in the disturbed forest transect, while the plantation transect had 23 species including eight woodpecker species. More woodpeckers were seen in plantation than in the natural (disturbed) forest.

Based on their predominant foraging behaviour, woodpeckers were segregated into the following groups: Non-specialists or gleaners - *Dinopium benghalense* and *Celeus brachyurus* (where gleaning constituted more than 60% of foraging activity); Specialists - *Picoides moluccensis, Chrysocolaptes lucidus* and *Hemicircus canente* (where excavation and pecking combined accounted for 85% or more of foraging behaviour) and intermediate or opportunists - *Picus xanthopygaeus*, *Picus chlorolophus*, and *Picoides mahrattensis*. *Picus xanthopygaeus* represented by fewer samples, spent more time on ground and besides, was found only in plantation, hence is omitted from further detailed analysis. Foraging behaviour of all species was more or less consistent in both habitats.

Visual examination of the plotted data reveals that there were virtually no differences among species in the use of foraging substrate condition. Seventy percent or more of foraging was done on live substrate by all species with the exception of the *Picoides mahrattensis* which foraged more (44%) on dead substrates in the natural forest. There were no major differences between the two habitats. Birds differ in their use of foraging substrate size, while the smaller woodpeckers - *Hemicircus canente*, *Picoides moluccencis*, *Picoides mahrattensis* and *Picus chlorolophus* foraged mostly on smaller substrates (>50%), the larger species *Chrysocolaptes lucidus*, *Dinopium benghalense* and *Celeus brachyurus* foraged on a combination of medium and large substrates. There were striking differences in the woodpeckers' use of DBH classes between the two habitats. While all species tended to use trees with larger DBH in natural forest in greater proportion (>50%), in the plantation, trees in the medium and small classes were used more often (>75%). All species in natural forest used taller trees in comparison to the relatively medium-sized trees used in the plantations. *Celeus brachyurus* foraged on small and medium sized trees consistently in both habitats. All woodpeckers used tree species in similar proportions in both the habitats. In the natural forest, *Terminalia paniculata*, followed by *Grewia tilaefolia* were the most frequently used trees, while *Tectona grandis* was the least used. In the plantation, *Tectona grandis*, followed by *Bombax ceiba* were the major trees used. *Picoides moluccensis* foraged more on *Bombax* spp. at both sites. Except in the case of *Picoides moluccensis* and *Hemicircus canente*, all other woodpeckers used tree species in proportion to their availability.

There were no differences in foraging behaviour, substrate condition and DBH size used in any of the species in natural forest sites while in plantation, substrate size and condition remained constant in all seasons. Larger sized substrates were used less frequently in the dry season by *Dinopium benghalense* and *Chrysocolaptes lucidus* in the natural forest. In the plantations, both the *Picoides* species gradually decreased the use of trees of medium DBH classes and increased their use of trees in the smaller and larger classes in the dry season. In the natural forest, woodpeckers tended to forage less frequently at lower heights as the dry season progressed, with corresponding increase in the use of medium and top height classes. Such a clear pattern was not seen in the plantation, though generally there was an increase in the frequency of foraging at the top height class.

A total of 63 nests of all eight species together were located during the study period. This includes 20 'old'

nests (18 *Chrysocolaptes lucidus* and 2 *Celeus brachyurus*) a nest of *Celeus brachyurus* that was used in both the years and another of the same species that was located on the same tree but in a different *Crematogaster* ant nest. December to May appears to be the principal nesting season for woodpecker species at the Peechi-Vazhani sanctuary, as most of the nests were found in this period. *Chrysocolaptes lucidus* alone appears to be having an extended nesting season during the South-west monsoon period.

Four species of woodpeckers (*Dinopium benghalense*, *Celeus brachyurus*, *Picoides mahrattensis* and *Picus chlorolophus*) nested both on trunk and branches while *Chrysocolaptes lucidus* nested exclusively on the trunk. The remaining three species nested exclusively on the branches.

The nesting substrates were live in 30 nests (53.6%) and dead in case of 26 (46.4%) nests. Further, six (20%) of the nests on live substrates had broken tops or fungal conks near the nest holes, while 22 nests (85%) on dead substrates were characterized by presence of fungal conks broken tops and lack of bark on nest branch. Nest heights ranged from 2.13 m to 15.24 m. *Picus xanthopygaeus* had the lowest mean height (5.8 m) while *Picoides moluccensis* had the largest (10.0 m). The nest-hole orientation appears to be random, though fewer holes are oriented between the azimuth 316 degrees to 90 degrees. There was considerable variation among individual species. Nest hole diameter ranged from 3.18 cm to 15.24 cm. Nest holes of *Chrysocolaptes lucidus* were significantly larger than those of the two *Picoides* species. Sixty two nests were located on 17 species of trees. Among these, *Terminalia paniculata* was the most frequently used, having ten nests of five woodpecker species. This was followed by *Tetrameles nudiflora* - 9 nests (all *Chrysocolaptes lucidus*), *Tectona grandis* (8), *Bombax* spp. (7), and *Grewia tilaefolia* (7). Fourteen of the nineteen nests (73.7%) of *Chrysocolaptes lucidus* were located on the two tree species *Tetrameles nudiflora* and *Bombax insigne*.

Nest tree heights ranged from 4.8 m to 28.96 m. *Chrysocolaptes lucidus* nested on taller trees than *Picus xanthopygaeus* and *Picoides mahrattensis*. The relation of nest height versus tree height differed from species to species.

Nest sites of *Chrysocolaptes lucidus* differed significantly from the nest sites of *Picus xanthopygaeus*, being located in more mature forest having more trees in larger height and DBH classes, with more basal area and greater average canopy heights. *Picoides mahrattensis* nests were located in areas with shorter trees and differed significantly from those of *Chrysocolaptes lucidus* in both parameters involving tree heights. Nest-sites of *Picoides moluccensis* also differed from those of *Chrysocolaptes lucidus* in having significantly lower average canopy height values.

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TITLE	**The avifauna of the tropical dry evergreen forests of Point Calimere Wildlife Sanctuary, Tamil Nadu**
STUDENT	**S. Alagar Rajan**
GUIDE	**Robert B. Grubh**
YEAR	**1995**
UNIVERSITY	**Bombay University**

Summary

The natural forests occurring in different biogeographic zones of India are undergoing detrimental changes owing to various anthropogenic activities, and the Tropical Dry Evergreen Forest (TDEF) is the most affected. This forest type comes under the Coromandel biogeographical province of the Indo-Malayan realm and presently covers only 0.13 percent of the total forest cover in India, and is fragmented. Less than 1% of the main TDEF habitat type is included in protected areas. The Point Calimere Wildlife Sanctuary in Southern India (10°18'N; 79°51'E) has a small patch of 24 km^2 of this forest, and it is one of the largest remnants of this forest type.

Although the avifauna of various forest types have been extensively studied in India, very little published information is available on the birds of the Tropical Dry Evergreen Forest type. The present study was, therefore, aimed at gathering ecological data on the birds of Point Calimere Wildlife Sanctuary, which accommodates one of the large remaining patches of TDEF. The study was designed to fulfill the following objectives:

i. To assess the status of the terrestrial birds of Point Calimere Sanctuary, including the seasonal occurrence of migratory birds.
ii. To study the bird community structure (i.e. species richness, density, and abundance) of the forest.
iii. To determine the habitat utilization patterns of these bird species.

During the present study, an attempt was also made to understand the impact of disturbances on the avifauna of the TDEF, with a view to develop an action plan to improve this endangered ecosystem to a healthier state. The field study was carried out from March 1991 to April 1993. The results are summarised as follows:

The terrestrial birds recorded so far at Point Calimere amount to 146 species. Sixty-seven species of resident birds were recorded, of which 24 species are ground-dwelling birds. The rest of the bird species are mostly arboreal. The most common resident birds of the sanctuary are the Whitebrowed Bulbul *Pycnonotus luteolus,* Whiteheaded Babbler *Turdoides affinis*, Common Myna *Acridotheres tristis*, Redvented Bulbul *Pycnonotus cafer* and Spotted Dove *Streptopelia chinensis.*

Fifteen species of seasonal local migrants were recorded. Among them, species such as Orangebreasted Green Pigeon *Treron bicincta*, Koel *Eudynamys scolopacea*, Brahminy Myna *Sturnus pagodarum* and Blackheaded Cuckoo-Shrike *Coracina melanoptera* were seen seasonally, depending upon the availability of food resources.

The number of bird species recorded in the sanctuary was minimum (21) during August and maximum (40) in December. Out of the total number of species recorded in the sanctuary, 64 were migrants. From an analysis of the bird banding data, it was possible to determine the dates of the arrival and departure of these species. Some of the common winter migrants are Brown Flycatcher *Muscicapa latirostris*, Brownbreasted Flycatcher *M. muttui,* Blyth's Reed Warbler *Acrocephalus dumetorum*, Largebilled Leaf Warbler *Phylloscopus magnirostris*, and Dull Green Leaf Warbler *Phylloscopus trochiloides*. The occurrence of Rubythroat *Erithacus calliope*, at Point Calimere was an interesting extension of its known range of distribution. The migratory terrestrial birds visiting Point Calimere appeared to be drifters (changing the wintering sites every year), rather than 'settlers' (visiting the same wintering site every year), as indicated by the recapture and recovery data. The current status and seasonal occurrence of the birds is dealt with in detail. Although several species of waterbirds were also recorded in the forest, they are not considered for any analysis.

Population studies of the birds were carried out following variable-width transect method. Although 146 species of birds were recorded, only 56 were encountered during the census. The mean number of species varied between habitats and it was found that disturbed habitat attracted more species than the undisturbed/least disturbed habitat. The relative mean density of bird species varied between sites. In all the study sites, except in moderately disturbed habitat, the Whitebrowed Bulbul was the dominant bird species followed by Whiteheaded Babbler, whereas in the case of moderately disturbed habitat, the dominant species was the Common Myna. The least disturbed forest area was the only site where the Red Spurfowl *Galloperdix spadicea* was recorded.

Forty-five species of plants were recorded to be used by these birds for feeding and resting. The most preferred tree was *Manilkara hexandra.* Height utilization of bird species was recorded. The use of different vegetation layers (vertical stratification) varies between bird species. Thirty-three species of birds were found to utilize the tree layer between four and five metre height in all except the least disturbed habitat, where it was between three and four metres. Predominantly ground birds such as Grey Partridge *Francolinus pondicerianus,* Larks, Pipits, Wagtails and also Doves, Whiteheaded Babbler and Common Myna preferred the forest openings. Canopy utilization by the birds has also been recorded. The different canopy regions used by birds are quantified. A majority of the arboreal bird species (45) observed at the transects were found to use the top outer canopy region at the maximum.

Nesting habitat preference of the breeding birds commonly seen in the study site was recorded. The details such as nesting tree species, nest height, and other nesting micro-habitats are presented. Altogether 31 species of plants were utilized by these birds for nesting. The number of plant species used by individual bird species for nesting varied between habitats. The maximum number of plant species (15) were used by Whitebrowed Bulbul, followed by Redvented Bulbul (13).

The major threat facing the sanctuary is cutting of trees by the villagers for both firewood and

construction of huts. Most of the tree species thus cut come under species much preferred by birds. Collection of leaf litter for manure by local people is one of the causes for the low regeneration rate of the forest plants, as seeds are also taken away along with the litter. Fruits of certain plants are being collected and sold by the local people. This practice not only deprives the birds of their food, but also affects the regeneration of plants. Invasion of *Prosopis juliflora* into the forest is also a serious threat to the forest, as it may slowly replace the native vegetation in the course of time. The effluents let out by the salt-based industries enter the forest and devastate the flora.

Some of the management recommendations are: 1. Forming a fire-wood depot, where commercial firewood like Casuarina, and Prosopis is stocked and sold at subsidised rates in order to avoid pressure on the forest for firewood. 2. Collection of litter as well as fruits must be stopped to improve the regeneration rate. 3. Removal of *Prosopis juliflora* has to be implemented at the earliest in order to avoid further invasion of this plant into the forest. 4. Nursery-raised native species of plants may be planted along the edges of the open areas and also in those areas which were wooded historically. 5. No untreated effluents from the industries located near the sanctuary should be let out.

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TITLE **Study on bird community structure of terai forest in Dudhwa National Park**
STUDENT **Salim Javed**
GUIDE **Prof. A.H. Musavi**
YEAR **1996**
UNIVERSITY **Aligarh Muslim University**

Summary

Avian communities, by virtue of being ecologically diverse, are one of the most suitable biological materials for monitoring the health and functioning of an ecosystem. The diversity and richness of avian species in a community also mirrors the diversity and richness of the habitat. A large number of studies have explored this relationship. Study on the Bird Community Structure of Terai Forest in Dudhwa National Park was started in 1991, as there have been no studies in the Terai region. This region has witnessed some of the most drastic changes owing to the changed land use pattern and is also ornithologically poorly known.

This study has been conceived to address certain questions regarding the avian community structure and to test whether the much discussed relationship between Bird Species Diversity (BSD) and Foliage Height Diversity (FHD) is applicable or not. The study also attempts to explore features of habitat that determine the avian community structure. The study also focused on studying avian guilds using an objective approach.

The objectives of the study were to:

1. Conduct bird community studies in moist deciduous "terai" forest of Dudhwa National Park.
2. Evaluate bird species diversity (BSD), bird species richness (BSR), relative density and composition over a period of time.
3. Determine how various habitat parameters affect the species diversity and density.
4. Investigate the effects of management activities.
5. Determine the guild structure of birds.

The study was conducted in Dudhwa National Park which is one of the finest representatives of terai habitat (moist deciduous Sal forest interspersed with subtropical tall wet grassland). Of the eight permanently marked transects, monitoring on a regular basis was done for six transects, two in the forest areas and the remaining four in grassland.

The tree species density was maximum in the riparian habitat with 01.2 trees /ha, followed by Sal Forest with 571.9 trees /ha. Density in wooded grassland was 157.8 trees /ha and was comparatively higher than the two other grassland sites.

Riparian habitat was also most diverse and rich with diversity value (H') of 2.46 and richness index of 2.95. This was significantly greater than the diversity and richness values of tree species in the Sal forest. Similarly, shrub species density and diversity value were also highest in the riparian habitat with 2094.8 shrubs/ ha.

Spearman rank correlation shows that most of these variables are intercorrelated, showing positive relationship, significant at ($P<0.01$ or $P.<0.01$). Principal Component Analysis (PCA) was performed to reduce the dimensionality. PCA plot on axes 1 and 2 show all the four grasslands clustered at one place either by virtue of low tree density or presence of some similar species. The riparian habitat was positively loaded on both the components whereas Sal forest was positively loaded on the PC-I and negatively loaded on PC-II. The first PC axis explained about 74% of the variance in data sets.

Ordination based on other vegetation variables such as density, diversity, species richness and number of tree and shrub species showed PC-I and PC-II accounting for 87% and 7% of variance respectively. PC-1 can be interpreted as tree species dependent and PC-II as shrub species and vertical heterogeneity dependent components.

Number of layers in the Sal forest was maximum as all the 18 height classes were present. This was followed by riparian and wooded grassland with 14 height classes. Foliage height diversity (FHD) value showed corresponding results as FHD was maximum for Sal forest and lowest for the Navalkhar grassland.

Maximum density values were obtained for the wooded grassland of Gajran (23.64 ± 1.204 birds/ha), followed by the riparian habitat (15.15 ± 0.999 birds/ha). The lowest densities were observed in the two most specialised habitats, the tall grasslands of Kakraha and the Sal Forest. All the density values had narrow confidence limits.

Summer densities at the transects differed from the densities in winter and was clearly evident in the wooded grassland which showed lower density. This decline can be attributed to two factors, i) the number of passerines in winter augment the densities, ii) whereas in summer this area has low number of breeding birds by virtue of being disturbed.

In Dudhwa the bird densities varied in summer and winter though the differences were not statistically significant (K-Wallis $X^2=5$ at $P>0.45$). On a broader habitat scale, density values did not differ significantly between habitats. Overall density was higher in the forest habitats. The lowest density was observed in the tall grassland habitat of Kakraha, both during winter and summer.

Distribution pattern of birds in Dudhwa, in general, conforms to the log-normal pattern, as species are distributed in a manner that the maximum number of species are represented by only a few individuals. Species with one or two individuals constitute 1-2% of the total individuals detected and have been categorised as rare.

The lognormal curve was fitted for each transect using two estimates. Wooded grassland of Gajrola (GJWG) at parameter $a = 0.267$ and $So = 18$, gave total expected species in the area around 106 to the observed number of 105 species. Curve for the tall grassland at Kakraha (KKTG) with 74 observed species was best fitted with $a = 0.207$ and an expected number of 77 species at $So = 14$. A total of 102 species were observed at PCSG and the number of species that were expected as shown by the model were 96.

At the two forest sites the fitted curve was more normally distributed. Species observed at the riparian habitat FLRF transect was 103 which was about three short of the expected number of species about 106. At Sal forest the observed species (70) was lowest when compared to the other transects. The best fit to the distribution of birds at this transect was provided by the model with $So = 15.5$ at $a = 0.355$ as the number of species expected was 74.

The abundance pattern of birds when fitted with the distribution model using two iterative estimates, was closer to the observed number of species with one of the estimates and the fitted curve was close to 'normal' bell shaped. This is indicative of the fact that the bird data to which the curves were fitted were derived from sufficiently large samples which showed limited truncation, as the veil line in most of the area was close to the origin of the curve.

Cluster analysis shows two main guild subdivisions, A and B. A contains all the species which forage in the higher canopy and B contains largely those species which are ground foragers or those which forage in the lower strata of vegetation. Seven different guilds comprising 30 species out of a total of 52 were identified.

The Principal Components Analysis (PCA) of all the 52 bird species yielded two components; PC-1 and PC-II foreign values greater than one explained 45.80 and 5.16 of the total variation in the data respectively. The first PC-axis explained 9.8% and the two axes together accounted for 97.9% of the total variation in the data set.

The PCA-1 segregated species confined to lower strata which forage by hawking, gleaning and pecking (positive values) from those which forage largely by gleaning and probing. Differential use of different substrata of the area, along with the body size have been the two factors for separating the species on PCA-1. The PCA-2 explained a small amount of total variance but has much significance as far as interpretation of data is concerned. Species along the axis-2 were segregated according to the foraging mode and again the use of different strata. The species were segregated by two factors along this axis, the body size and foraging method. All species which either forage on ground or lower layer of vegetation show positive value, and all those species which use higher canopy, are of small body size and mostly forage by foliage gleaning and probing and sallying, show negative loading on the PCA-2.

Bird species in Dudhwa forage using eight different modes, of which gleaning is the most common, accounting for more than 50% of the total observations, followed by pecking and sallying. Plant height is significantly correlated with branch glean, branch probe, branch peck, trunk glean and trunk probe. Plant height has again been significantly correlated with hovering on foliage and bark glean ($r=0.4388$ and 0.4766; $p<001$). Ground gleaning and ground pecking was negatively correlated with PHT ($r=0.6161$ and 0.4367 at $P<0.001$).

Determinants of guild structure were identified by varimax factors rotation which extracted seven factors. The seven rotated factors accounted for 83% of the total community variance. The first factors explained the maximum variance of 8.3 followed by second factor which explained 7.25 and in the same decreasing order by the subsequent factors. Percent variance explained by the first rotated component was 26.9%, 23.3% by the second and 7.46% by the third.

The high values, whether positive or negative, signify that there are few important variables which explain and determine the guild structure. Factor-I has high positive values for foraging maneuver associated with bark, trunk and branch substrates and is interpreted as the bark foraging, and it signifies the importance of this factor in the guild determination. Second factor is easily interpretable as height related factor, as shown by the high positive loading for foraging activities confined to the ground. Factor-4 showed high positive loading for foliage gleaning and is important determinant of guild.

Factor-5 shows a very high positive value for all the variables involving hovering over substrates. The fifth factor explained about 7.5% of the total community variance. Factor-6 accounts for only 5.8% of the total community variance and is not very clearly interpretable.

The results from Cluster Analysis, Principal Component Analysis and Varimax Factor Rotation highlight the importance of the vegetation structure in determining the guild structure and the community structure of the area. Features of vegetation such as height, number and type of strata, along with the foraging behaviour and body size are some of the key factors in explaining the community pattern and guild structure.

Bird species diversity was maximum for the wooded grassland. There was no significant difference between BSD values in summer and winter at this site ($t=0.43$, P.0.67). Mean bird species richness (BSR) also showed no significant difference between summer and winter ($t=0.01$, $p>0.98$). The two other grassland sites, with short grasses showed lower values of species diversity and richness when compared to GJWG. BSD values differed significantly from winter to summer ($t=3.14$, $P<0.007$) for these sites.

Species diversity and richness remained more or less constant in tall grassland of Kakraha as no difference was observed. Mean BSD in summer was higher than in winter but the difference was not statistically significant ($t=1.23$, $P>0.24$).

Except for wooded grassland (GJWG) transect, the bird species diversity in the riparian habitat was higher than all other transects for all the years. The greater structural diversity of habitat is responsible for higher BSD values when compared to the Sal forest, which is less diverse. BSD did not differ significantly between summer and winter ($t=0.94$, $P>0.33$) and same was found with BSR. BSD in winter was lower than the summer and was statistically significant ($t=3.84$, $P<0.002$) winter ($t=4.88$, $P>0.0004$).

BSD values were maximum for the wooded grassland of Gajrola. Overall bird species diversity at Gajrola was significantly different from all the habitats except for the riparian forest (mean 2.89 vs. 2.79, $t=1.7$, $p>0.95$, one tailed test). BSR for all the sites showed a similar pattern except for differences between GJWG and FLRF (mean vs., $t=4.68$, $P<t=0.0001$) and KKTG and PC (mean vs., $t=3.82$, $P<t=0.0008$) were significantly different (mean 2.62 vs. 2.74, $t=1.68$, $P>0.11$). A

Spearman rank correlation coefficient showed no significant relationship between bird species diversity and richness with habitat variables. Relationship between BSD and FHD was not found. Shrub species richness was the only variable which showed a significant relationship (r=0.88, P<.01) with BSD.

Stepwise multiple regression analysis was performed to construct habitat models. Three models, one general (summer and winter together) and one each for winter and summer, were constructed using nine habitat variables (TDEN, TDIV, TRICH, TCOV, SDEN, SDIV, SRICH, TSN and FHD). BSD was used as the dependent variable.

The model for winter also used two variables, SRICH and the TRICH. They together explained 78% of the variance (R^2 = 0.78). Unlike the general model and winter model, the model for bird species diversity in summer was different, as only SRICH was significant explaining a total of 68% of the variance (R^2 =0.688).

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TITLE **Ecology and evolution of non-breeding distributions in the old world Leaf Warblers**

STUDENT **Madhusudan Katti**

ADVISOR **Dr. Trevor Price**

YEAR **1997**

UNIVERSITY **California State University**

Summary

Many studies have focused on the causes of mortality in animals. Migrant birds, in particular, have received much attention in recent years because of population declines in many species. Both breeding season and non-breeding season factors have been implicated in these declines, but there are few detailed studies in the non-breeding season. Here, I study factors affecting survival in the non-breeding season in a population of Greenish Leaf Warblers *Phylloscopus trochiloides* at a single site, Mundanthurai, in southern India. Over five years (1992-1997) winter rainfall showed considerable annual variation. I find strong positive correlations between rainfall and leaf production in the forest, arthropod abundance, and warbler density. I also find correlations between rainfall and several life-history features of the birds, such as fat storage and timing of annual molt. During winters of low rainfall, birds carry more subcutaneous fat. This may cause the observed delay in molt, with potential repercussions on future reproduction. I also examined the use of call notes in territory maintenance during the non-breeding season. I used playback experiments to test for the "dear enemy" effect among territorial neighbors, and do not find evidence to support it. I extend the understanding developed from the study of temporal variation in a single species to spatial patterns in the non-breeding seasonal distributions of other *Phylloscopus* species. I find that larger birds, both between and within species, over-winter at lower latitudes than smaller birds. This latitudinal decline in body size is the opposite to that commonly seen (larger body sizes at higher latitudes: Bergmann's rule). In India, during mid-winter, there seem to be more large prey in the south than in the north, explaining the presence of larger species. The importance of resources in affecting bird distributions is also indicated by within-season migratory movements throughout the Indian peninsula, which lack rainfall. Competition during the winter and timing of breeding may also play a role in determining non-breeding distributions.

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TITLE **Wintering ecology of the harriers of Velavadar National Park, Bhavnagar district, Gujarat**
STUDENT **Syed Asad Akhtar**
GUIDE **Mr. J.C. Daniel**
YEAR **1998**
UNIVERSITY **Mumbai University**

Summary

Harriers belong to the genus *Circus*, and are found throughout the temperate and tropical regions. Thirteen species of Harriers have been recorded to exist worldwide, comprising the Spotted Harrier *Circus assimilis;* the Longwinged Harrier *Circus buffoni*; the Cinereous Harrier *Circus cinereus*; the Western Marsh Harrier *Circus aeruginosus*; the African Marsh Harrier *Circus ranivorus*, the Eastern Marsh Harrier *Circus spilonotus*, the Pacific Marsh Harrier, *Circus approximans*; Madagascar Marsh Harrier *Circus maillardi*; the Black Harrier *Circus maurus*; the Pied Harrier *Circus melanoleucus*; the Hen Harrier *Circus cyaneus*; Pallid Harrier *Circus macrourus* and Montagu's Harrier *Circus pygargus*. Most Harrier species are migratory. All the Harriers are ground nesters, except the Spotted Harrier which nests on trees. Five species, the Marsh Harrier, Montagu's Harrier, Pallid Harrier, Hen Harrier and Pied Harrier, occur within Indian limits. Only one, the Pied Harrier *Circus melanoleucos*, occasionally breeds within our limits in winter, while the rest are winter migrants.

Harriers are open country daytime-active (diurnal), slim and elegant birds of prey. The group contains longwinged, longtailed raptors easily identified by their slender shape and buoyant flight. All Harriers show reversed sexual size dimorphism i.e. the females are larger than the males. They have a longish tail and very long wings relative to their body weight. Their buoyancy in the air allows them to forage for extended periods, some like the Hen Harriers have been estimated to cover 160 km a day. They rarely perch on a tree but rest on ground, on a stone or tussock. They have a very typical Circinine flight. Alternately flapping and gliding on wings held up in a shallow V, they systematically quarter the ground in search of prey, which consists of small reptiles, mammals, insects and weak or wounded birds. A more or less conspicuous ruff of close set, soft feathers extending across throat and up each side of neck behind ear coverts gives rise to their pronounced facial discs concealing large ears, which along with their sharp sight aids them in effectively pin pointing their well camouflaged, inconspicuous and unwary quarry.

The Velavadar National Park, Bhavnagar Dt., Gujarat, is considered to be the world's largest roost of wintering harriers. The Park is located in a semi arid area of alluvial plain popularly known as the *Bhal*, which literally means the forehead i.e. a bare open landscape. The grassland vegetation of the Park provides the typical habitat essential for harrier roosts. The Velavadar roost has been in prominence since the early eighties and has become a major tourist attraction as well as a focus of ornithological studies.

The existence of the grassland habitat of the Park is vital to the continuation of the roost, which is complemented by the cropping pattern presently prevalent in the *Bhal* and the mosaic of habitats around the Park, which includes cotton, wheat and jowar fields, saline lands, marsh lands and *Prosopis* scrublands. The variety of habitats favours the foraging activities of the Harriers by providing them with wide unhindered foraging grounds and an abundant locust prey. No disturbance is caused to the foraging birds by the local farmers.

Except for cursory studies by earlier visitors to the Park, no indepth and longterm study was conducted on the roost and the foraging activities of the Harriers. Hence, it was felt that the roosting and foraging activities should be studied extensively and the various factors, strengthening the continuation of the roost should be investigated and documented. It was also felt necessary to highlight the beneficial role of the Harriers in the area's agricultural economy.

The study had the following objectives:

1. Assess the abundance, species composition and age structure of the Wintering Harriers with regard to the roost at the Velavadar National Park.
2. To determine the roosting site preference and study the pre-roosting, roosting and post-roosting behaviour of the Harriers.
3. To determine their habitat use and preference.
4. To study the foraging behaviour of the Wintering

Harriers and assess their food composition from pellet analysis.

This study focused on the wintering ecology of the harriers and highlighted the activity rhythm of the harriers with regard to their use of the grassland habitat as a communal roost and the surrounding croplands and the *Prosopis* scrublands as their foraging grounds. The beneficial role of the harriers in controlling the locust population in the croplands around the Park was also emphasized.

The study also focused on the behavioural aspects of the harriers on the roost, especially with regard to their pre-rooting, roosting and post-roosting activities. Their foraging activities were also studied. The age and species composition of the Harriers on the pre-roosting sites and the habitat preference of the species on the foraging grounds were also investigated.

The results are summed up as follows:

The Montagu's formed the most abundant harriers, followed by the Pallid. Very few Marsh Harriers were observed on the roost. The Hen Harrier, though seen during an earlier study, was not seen during the present study. Juvenile Harriers mainly Montagu's and Pallid also formed a good population of the wintering harriers.

The harriers roosted in the grassland areas of the Park. The roosting was preceded by pre-roosting activity, which commenced at least an hour before sunset and continued close to sunset. The harriers pre-roosted in scattered groups and also individually in open patches like the saline lands and also on the Park's unmetalled roads. They remained still during this phase and faced towards the setting sun and at times preened their feathers. Foraging activity was absent during the pre-roosting phase. No inter- or intra-species agonistic behaviour was noticed during this phase.

The roosting activity peaked just before sunset and continued well after sunset. A lot of milling and movement between roosts took place before all the harriers settled down in the roost in the grassland areas of the Park. The roost comprised of one major roost and two or three satellite roosts, though at times only one roost was formed. Very few predations were noticed on the roost. The Montagu's Harriers were the first to leave the roost in the morning and flew high above the roost, while the Pallid Harriers departed later and flew low. The Harriers dispersed in all directions.

After dispersing from the roost the harriers post-roosted on open patches of ground, before commencing their foraging activities. They continued post-roosting almost an hour after sunrise. Their behaviour during post-roosting was similar to the pre-roosting phase, except that they sat with their backs towards the rising sun. During this phase also, no inter- or intra-species agonistic behaviour was noticed nor any foraging activity took place.

The harriers foraged mainly in the croplands around the Park, while some individuals foraged in the grassland and scrubland habitat also. The Marsh Harriers foraged in the moister areas, viz. along the edges of nullahs and the creeks in the peripheral areas of the Park. The Montagu's foraged mainly in the cotton fields and the *Prosopis* scrublands around the Park. Locusts formed the major prey item of the Montagu's Harriers. The Pallid Harriers foraged mainly in the grassland areas of the Park, and the wheat fields around the Park, though at times a few Pallids were also seen foraging in the cotton fields. They were mostly observed preying on small passerines and also on doves.

During foraging the harriers were well spaced out. Not more than two or three harriers could be seen at a time in a particular foraging area in the morning phase of their foraging activity, though in the evening phase several harriers could be seen in the same area, as they foraged and drifted gradually towards their pre-roosting sites or the roosting area. Inter- or intra-species agonistic behaviour was not noticed during the foraging activities. After a few successful strikes, the harriers tended to pause for a few minutes, before resuming their foraging activities, which tapered off as the harriers became satiated and the heat of mid-day set in. During mid-day, the harriers either rested in the shade of the cotton plants or clumps of grass or soared on thermals. Foraging activities were resumed during the later part of the afternoon.

The harrier roost is beneficial to the farmers in the area as the harriers feed extensively on the locusts in the crop fields and the scrublands around the Park. A very conservative estimate indicates that more than two million locusts are consumed in a season (October - March) by the harriers, during their foraging activities, thus keeping the number of locusts under check.

The following recommendations are given:

Colour marking and radio telemetry studies of the harriers should be initiated to understand their range of distribution from the roost at Velavadar National Park.

The grassland habitat needs to be protected from the invasion of the exotic weed *Prosopis chilensis,* which now covers almost 50% of the Park's area. A higher

budgetary allocation in the Park's budget should be made for *Prosopis* eradication and control.

The present cropping pattern around the Park should be maintained as it favours the foraging activities of the harriers, thus complementing the roost provided by the grassland.

The harriers are natural pest control agents. The economic aspect of the harriers in Velavadar National Park should be highlighted amongst the local farmers, who are indifferent to their presence, though they cause no harm to the harriers. The harriers should be promoted as allies of the farmers. An informative colour poster highlighting the beneficial role of the migratory harriers in the agricultural economy of the area should be made and distributed as part of a public awareness campaign.

The organic farming presently practiced by the farmers in the 'bhal' should be encouraged and any tendency to use synthetic pesticides and fertilizers should be discouraged. These eco-friendly aspects should be publicised in the posters to be designed for public awareness.

The roost can be an important tourist attraction and hence a source of substantial revenue to the Park authorities, provided necessary precautions are taken to keep the inherent disturbance due to tourism under check.

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TITLE	**Ecology and behaviour of Blacknecked Stork (*Ephippiorhynchus asiaticus*) Latham, 1790) in Dudhwa National Park, Uttar Pradesh, India**
SUPERVISOR	**Asad R. Rahmani**
STUDENT	**G. Maheswaran**
YEAR	**1998**
UNIVERSITY	**Aligarh Muslim University**

Summary

Storks occur on every continent of the world, and they are primarily associated with wetlands (marshes, swamp forest, waterbodies) or grasslands/savannas. Thirteen of the world's nineteen stork species are strictly tropical or sub-tropical. Five of the remaining six species range from tropical to temperate area. These include species primarily of the genus *Ciconiia,* the "true storks" and *Mycteria* the "wood storks".

The Blacknecked Stork *Ephippiorhynchus* [=*Xenorhynchus*] *asiaticus* (Latham) inhabits tropical Asia and Australia. The two subspecies are *E. asiaticus asiaticus* in Asia and *E. asiaticus australis* in New Guinea, Australia and intervening islands. They are differentiated mainly by the amount and colour of iridescence on the neck and head.

Though this species is thriving well in Australian region, it has declined steeply in the Indian subcontinent. On the global scale it is not a threatened species, but in the Indian subcontinent it may have reached critical population levels. Taking this into consideration, this project was launched in 1994 and Dudwa National Park was selected as one of the three field stations to study this threatened stork in India.

The main objectives of this study were to study:

i the behaviour of the Blacknecked stork during the non-breeding season.

ii the feeding ecology of the Blacknecked stork

iii the inter- and intra-specific interactions of the Blacknecked Stork.

No detailed study was conducted on this species except Kahl's (1973) comparative account of the breeding behaviour and a cytotaxonomic study (De Boer and Van Brink 1982).

The study was conducted from December 1994 to June 1997 in Dudwa National Park which is in the *Terai* region of Uttar Pradesh state of India and has got many wetlands which are small to big in size. Three wetlands were selected on the basis of the presence of the territorial Blacknecked Storks.

The data were collected only in the winter (November to April) and summer (May to July) seasons and during the monsoon (August to October) period no data could be collected. This was mainly because of the closure of the Park due to rainy season both for tourists and researchers.

To study the behaviour pattern of the Blacknecked Stork (BNS) during their post-breeding season, focal animal sampling (Altman 1974) was used. Activity of a single individual was recorded continuously (from 0600-1800 hrs) from watch towers situated in each wetland at a height of approximately 10-15 m. One full day was devoted to record the activities of either a male or a female BNS in one wetland. Next day another bird was observed

continuously so that two days were spent in each of the three wetlands alternatively to study the birds (male and female). For analyses the whole study period was divided into two seasons i.e., early (February and March) and the late (April to June) season. The Kruskal-Wallis tests were used to see whether there was any difference in the percentage of time spent on different activities by different pairs of BNS in DNP. Mann-Whitney U test was used to see the same difference between sexes. The only parametric test I used was student "t-test" (unpaired).

To study the foraging ecology of the BNS, five minute observations were made to record the following parameters viz. starting and ending time, number of pecks or jabs, number of fish caught, fish size, handling time, water depth and mode of food capture (tactile/visual). The Principal Components Analysis (PCA) was performed to find out the parameters which really determined the foraging success of the BNS in two years (1996 and 1997) in DNP. To find out the prey profitability, *Heteropneustes fossilis* fish were brought from the local fish market and their length (cm) and wet weight (gm) were estimated. The profitability curve was estimated by

$$\text{Prey profitability (g/s)} = \frac{\text{Wet weight of a fish (g)}}{\text{Handling time (sec)}}$$

One way Anova (F-test) was used to compare the male and female BNSs' total foraging time in different months. Again, one way ANOVA was used to compare the mean male and female BNSs' interfood interval recorded in different months during the study period.

To study the inter- and intra-specific interactions, chasing acts were recorded while taking data on the activity pattern of BNS. The time of aggressiveness shown towards conspecifics and the species reacted with, and their numbers were also recorded. Two sample t-test (unpaired) was used to compare the distance chased and the distance between two interacting species.

In order to study the breeding behaviour of a particular pair, a hide was put up on a tree branch approximately at a height of 17 m. Observations were made from 0600 to 1800 hrs. Data were collected from mid-September and so actual egg laying date was not known as the birds were already on the nest when I reached the area. Data were collected simultaneously in case both of them were on the nest together.

Time Activity Budget

The Blacknecked Storks (BNS) spent most of their time resting. The total time spent on this activity was almost 46%. The chasing or aggression (towards inter- and intra-species) was more among BNS during early period (February and March) ($\pm$ SE) (2.25 + 0.68) than late period (0.62 $\pm$ 0.21) (t=2.277, P<0.0306). Resting was more in the late (67.3 $\pm$ 2.45) than early (49.7 $\pm$ 6.58) season and this differed statistically (t=2.514, P<0.0165). In 1995, BNS of DNP spent more time drinking in the late season (summer) than the early season (winter) and this differed significantly (t=2.3017, P<0.0441). In 1996 no activity differed significantly among the BNS of DNP in the early and in the late season. Whereas in 1997, chasing activity differed significantly (t=2.8380, P<0.0219).

When data of three years were pooled together and analysed, I found that there was a non-significant difference for all activities in male and female irrespective of months and habitats. When the year-wise analysis was done, only wing stretching differed significantly between male (0.27+0.23) and the female (1.1 $\pm$ 0.00) (Z=2.436, P<0.014, Mann-Whitney U test) in 1995. In 1996 no activity differed significantly between sexes. Whereas in 1997 preening differed significantly between male (5.5 $\pm$ 2.80) and female (9.35 $\pm$ 0.91) (Z=2.606, P<0.0091). When data of all three years were pooled together and analysed all three pairs (Banketaal, Badhitaal and Kakrakataal pairs) spent almost equal amount of time performing different activities except Banketaal pair which rested more than the other two pairs (X^2=6.003, d.f. = 2, P<0.0013, Kruskal-Wallis test).

Foraging Ecology

The Blacknecked Stork prefers to forage in freshwater swamps, rivers, lakes with large trees, or at least one large tree some distance away. In Dudwa N.P. it has been observed foraging from open shallow wetlands surrounded by tall grass and woodlands. Kushlan (1978) has recorded 14 categories of foraging behaviour among storks and their relatives including the Blacknecked storks. Here in Dudwa, I observed four more feeding behaviour: bill vibrating, preening, wing flicking and jumping.

In Dudwa, the BNS mostly foraged by tactile and sometimes visual technique. Of the 929 fish seen or caught in two years (1996 and 1997), 894 (96%) were

caught by tactile mode of feeding and the remaining 35 (4%) were caught by visual mode of feeding.

In March and April 1996, the peck rate of male and female did not differ significantly, but in May number of fish caught varied significantly. Male (1.89 ±1.69) caught more fish than female (0.78 ± 0.85) (Z=2.025, P<0.042). In May, female (39.8 ± 23.2) peck rate was more than male (18.2 ±11.0) and differ significantly (Z=3.007, P<0.0201), whereas the number of fish caught did not differ significantly. Even though the peck rate of female was higher than the male, her fish catching or success rate was less than male. This could be the reason for female BNS's prolonged foraging period (39.8 ± 27.7, F_3 = 91.9, P<0.05) that resulted in increased peck or jab rate.

The male and female BNS look more or less similar in their morphological features or characters so there should not be any difference in their foraging efficiency. However, I found a slight difference in their foraging ability: the male was somewhat voracious than the female and it was evident from its success rate.

The interfood interval is defined as the period between obtaining successive food items. The interfood interval varied among male and female BNS in different months. The mean interfood interval varied betwen sexes in March 1996. The male BNS's interfood interval was higher than the female. In 1997, interfood interval of male and the female BNS differed significantly in all four months of study. However the total time foraged did not vary between sexes in different months except February. In February even though the total time (in minutes) foraged was apparently not much different between male (79.0 ± 54.0) and female (70.5 ± 10.6), it varied statistically ($F_{2,1}$ = 25.9, P<0.05).

Simple Linear Regression analyses show that the time required to swallow fish increases with size in 1996 for male BNS (r^2=0.427, P<0.0001). The female BNS's time taken to handle fish increased significantly with that of size (r^2 =0.578, P<0.0001). In 1997 also the male (r^2=0.54, P<0.001) and female (r^2=0.378, p<0.0001) BNS's time taken to consume a fish increased as the fish size increased.

In 1996, the first principal component accounted for 34% of total variance. The highest correlations are with size, number of fish, prey handling time, month and water depth. The second component accounts for an additional 23% of the total variance. The number of pecks or jabs showed highest (0.46) factor loading and was highly correlated. The third component accounts for an additional 16.8% of the total variance. The water depth showed a positive loading (0.66) followed by number of pecks. The Spearmann's correlation matrix shows that size varied according to season in 1996 and this in turn imposed a considerable impact on other variables like handling time, number of fish the adult BNS caught in every five minute foraging bout. And beyond this, water depth too contributed a little in BNS's foraging success.

In 1997 there was a considerable change in the foraging pattern of BNS. Based on direct observation I presume that the change might have occurred largely due to two reasons. One was because of change in water level due to rain the Park received in late 1996 and another was of successful breeding of almost all focal pairs. The first component accounts for 37.2% of total variance. As that of 1996, here too all other values of PCI had positive values except number of pecks. Here it was month which showed high (0.75) factor loading. The second component accounted for an additional 24.3% of the total variance. Handling time had high (0.78) loading followed by number of fish caught (0.61). I interpret PC-II as "handling time" factors. The third component accounts for an additional 13.9% of the total variance. I interpret PC-III as a number of fish dependent factors. In 1997 the parameters such as month, handling time, number of fish the adult BNS caught and number of pecks or jabs, determined the foraging success of adult BNS.

When I offered 19 fishes of *Heteropneustes fossilis*, the mean handling time was lowest for the biggest size class (i.e, fish of 6 cm, n=3) and highest for the smallest size class (i.e., fish of 4 cm, n=3) (r^2=0.1673, P>0.001). This inverse trend must have had a real impact on the profitability (r^2 = 0.001) also.

Inter- and intra-specific interactions of BNS

The Blacknecked stork is a highly territorial bird. My general observations indicate that the territoriality increases as food depletes. The aggressive act of BNS being when it sees any intruder (both inter- and intra-specific) which is foraging actively and this could pose some impact on the continuous flow of prey availability to the BNS. Totally 17 species (including BNS) were observed interacting with BNS, of which Spoonbill interacted most (67.4%) followed by Whitenecked Stork (16.6%). On a few occasions, it was observed that BNS accepted the presence of Spoonbills and other piscivorous birds. This was only when they (BNS) were very hungry and were actively foraging and had no time to chase other birds.

Majority of intruders were chased by BNS when they (intruders) were actively engaged in foraging. Only a few resting birds were disturbed by BNS and they were of their own family (Ciconiiformes) such as Whitenecked Stork, Lesser Adjutant Stork, Painted Stork and Openbill Stork.

I have rarely seen a BNS physically attacking any intruder, instead it gives a strong threat signal by clattering its bill loudly, thereby deterring an intruder. In case if an intruder fails to respond to this higher profile threat display, the BNS starts chasing the same until the opponent disappears from the territory fully or settles somewhere far away from BNS's foraging territory. Chase distance varies according to the species involved with BNS. I have seen Spoonbills being chased by BNS for a long distance. This might be due to their high density and competition for the same food resource. The chase distance of the male and female BNS did not vary significantly in all three years.

In the absence of other potential waders, it was Large Egret which came under severe threat by foraging BNS in all wetlands of DNP. So, whenever a Large Egret arrived the BNS used to react immediately whatever the distance may be.

The Mann-Whitney U test results shows that there were no significant difference between male and female BNS chasing away the intruders under different category in three different years. The Kruskal-Wallis results show that there were no significant differences among the BNS in chasing away the intruders under various distance categories in different water levels in 1995 and 1996, but in 1997 there occurred a significant difference in different water depths (X^2 = 15.18, d.f.=3, P<0.0017). When data of all three years were pooled together and tested, there occurred a significant difference (X^2=34.68, d.f.=3, P<0.0001) according to different water level change.

Breeding biology

Most nests of the Blacknecked Stork (BNS) in India were located at 6-25 m above the ground and have been found on trees such as Kadamb (*Acanthocephalus kadamba*), peepul (*Ficus religiosa*), and simul (*Bombax malabarica*). In Dudwa a pair nested on the kheima (*Adina cordifolia*) tree at a height of nearly 20 m.

In Dudwa, the Blacknecked Storks prefer to build their nests (n=4 nests) on tall trees situated amidst tall grasses. The distance from the nearest water sources varied from 300-500 m. The nest which I studied intensively had the nearest human habitation at a distance of 120 m (forest post on Indian side) and the nearest agricultural field at a distance of 140 m inside Nepal.

Both the male and the female leave the nest frequently to collect the nest materials. Time taken to return to the nest varied greatly between sexes and in different months. On an average, the BNS spent 10.4% of its time in bringing nest materials and 2.03% of its time in bringing water. Both parents brought water more often during mid part (1000-1400 h) of the day. The BNS mostly used dried grasses for nest insulation and they were collected from the nearby places (within a radius of 200 m).

When I started studies in September 1996, incubation was going on. Even during the incubation period, once I saw mating on the nest. Actual hatching dates could not be found out, but most probably the first chick hatched on 17th October 1996. This was further confirmed on the basis of food brought by parents on 19th. During early part of the day, the chicks were protected from the cold wind by parents sitting over them or being placed between their wings. As the chicks grew, begging posture developed and the begging call was clearly audible at a distance of 70 m. At about 27 days, the juveniles were left alone on the nest by parents for short periods. At the age of almost 50 days, the chicks started jumping on the nest, and in another ten days they started wing flapping and attempting to take-off for brief flights.

The Blacknecked Stork pair was very attentive at the nest with either male or female, or both, remaining at the nest until the chicks were several weeks old. This was mainly to give protection to the chicks. I found that the parental investment of a male and a female BNS is almost equal. As the young ones gained strength to stand on the nest (7-8 weeks) the time spent on the nests gradually diminished. In the case of male, the percentage of time away from the nest was more than female and this differed statistically (Z=2.012, P<0.0443). In the case of male, time spent away was more during later part of the day (1400-1800 h) followed by early morning (0600-1000 h).

In total, the Blacknecked Storks spent 4.8% of their time maintaining their chicks, but the male spent a little higher time than the female.

On 22 October, 1996 approximately two days after

chick hatching I saw the male BNS feeding on fish from the nest floor. The focal pair spent 4.38% of its time feeding the chicks. The male BNS spent 4.69% of its time in feeding the chicks and the time duration taken for this differed statistically in different months (X^2 = 16.082, P<0.0029) and different chick stages (X^2 = 21.612, P<0.0006). Male fed the chicks more during early part (0600-100 h) of the day and this exactly coincides with more time it spent on the nest during this part of the day. Whereas the female spent 4.60% of its time in feeding the chicks, her chick feeding activity did not differ statistically at different chick stages. She spent more time on this activity during mid part of the day (1000-1400 h) followed by later part (1400-1800 h).

Both the male and the female almost spent equal amount of time in feeding their young ones throughout the breeding season.

Preening is a common activity of the Blacknecked Stork and focal pair spent approximately 11.2% of its time preening and this differed statistically between months (X^2 = 35.184, P<0.0001) and different chick stages (X^2 = 28.065, P<0.0001).

The focal pair spent only 0.775 of its time in reingesting the food which was regurgitated for the chicks. This differed statistically between different chick stages (X^2 = 17,200, P<0.0041). The male BNS spent 1.02% of its time for this activity and this differed statistically (X^2 = 15.287, P<0.0092) in different chick stages. Female spent only 0.34% of its time in reingesting the food material and this did not differ statistically in different chick stages (X^2 = 4.172, P>0.5250). Time taken for this activity did not differ between sexes (Z = 0.985, P>0.3247).

In total, the focal pair spent 14.9% of its time sitting and resting (this includes incubation and protecting chicks from environmental conditions such as cold and heat) and this varied statistically in different chick stages (X^2 = 65.055, P<0.0001). The male BNS spent 13.6% of its time resting and this varied statistically in different chick stages (X^2 = 41.309, P<0.001). Time spent on this activity was more during early part of the day (15.51%) and this could be due to the protection it gave to the juveniles during the colder part of the day as temperature dropped to single digit (°C) for a few days in December. Time spent by male and female on this activity differed statistically, female having spent more time (Z=2.054, P<0.0400).

The focal pair spent 2.03% of its time watering. This varied statistically in different chick stages (X^2 =19.095, P<0.0018). In the case of male watering was more during mid part (1000-1400 h) (0.04%) of the day. In the case of female BNS spent nearly 3% of its time watering and this differed in different chick stages (X^2 =14.642. P<0.0121). In general, the male poured or drooled more water than the female. The Mann-Whitney U test results show that both sexes drooled almost equal number of times (Z=0.941, P>0.3467), but as mentioned earlier, the male poured more (quantity) water than the female.

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TITLE	**Comparative ecology and behaviour of storks in Keoladeo National Park, Rajasthan, India**
STUDENT	**Farah Ishtiaq**
GUIDE	**Dr. Asad R. Rahmani**
YEAR	**1998**
UNIVERSITY	**Aligarh Muslim University**

Summary

There are around 2000 species of birds in the Indian subcontinent (Ali & Ripley, 1987) including the migrants which come during winter to this part of the world. These birds are distributed in wide range of habitats such as woodlands, grasslands, riparian, oceans and wetlands.

Around 58.4 million hectares of India comes under wetlands (Anon. 1993) and most problems in India's wetlands are related to human population. Of the 1200 species found in India, around 22% are totally dependent on wetlands. One of such groups whose population is declining at a fast rate are storks.

The storks belong to Class Aves, Order Ciconiiformes and Family Ciconiidae. There are 19 species of storks in the world (Kahl, 1968), of which 15 are regionally threatened. Tropical Asia and Africa have the largest concentration of storks in the world.

Eight species of storks have been reported from India (Ali & Ripley, 1987). The Painted Stork (*Mycteria leucocephala*), Openbill Stork (*Anastomus oscitans*), Blacknecked Stork (*Ephippiorhynchus asiaticus*), Whitenecked Stork (*Ciconia episcopus*), Lesser Adjutant Stork (*Leptoptilos javanicus*) and Greater Adjutant Stork (*Leptoptilos dubius*) are the resident species. The Black Stork (*Ciconia nigra*) and White Stork (*Ciconia ciconia*) are winter migrants.

The study at Keoladeo National Park, Bharatpur was carried out with the following objectives:

1. To study the feeding ecology of the four resident species of storks
2. To study the breeding biology of Whitenecked Stork and Blacknecked Stork
3. To study the reproductive success of colonial breeders
4. To study the habitat utilization by storks
5. To study the time budget of storks.

Different methods have been adopted to record data on various aspects. Data on the foraging behaviour were collected on four species of storks after making close observation on the feeding mode of birds and accordingly the parameters and time allotted to each bird. There was no sexual dimorphism among storks except for Blacknecked Stork where distinction could be made separately as male and female in the field. Observations were made for male and female birds once in a week when seen foraging between 0600-1000, 1000-1200, 1200-1500 and 1500-1800 hours for full day. I used "focal animal sampling" described by Altmann (1974). Information was collected continuously for 30 minutes period with a break of five minutes.

The observations on the foraging behaviour of Painted, Openbill and Whitenecked Storks were taken in the same manner with one extra parameter, namely the group size, as they forage in group.

It was difficult to find nests of a solitary breeder like the WNS which prefers to nest in dense trees while Blacknecked Stork was quite conspicuous as it prefers top canopy of the tree for nesting. All the nests were located by following individual birds collecting nesting material to the trees. The incubation period was observed from the ground without hide to minimize the disturbance and chances of nest abandonment. After hatching, systematic observations of the bird's activities at the nest were carried out with binoculars and telescope from hides 12 m apart from the nest and 12-15 m above the ground or depending upon the height of the nest. Data were collected on type of the prey brought to the nest and behaviour at the nest while feeding, nest building and other social activities of the birds. The observations were made throughout the day. The observations were divided by time of the day into three shifts as 0600-1000, 1000-1400 and 1400-1800 hours. The arrival trips of the adults were divided into different categories on the basis of the activities:

i. Number of trips to the nest which were further segregated into nesting material trip, watering trip and feeding trip.

ii. Different activities such as preening, guarding, feeding, nest cleaning and nest arranging and brooding of chicks relative to time of day and age of the chicks.

To calculate the breeding success of Openbill and Painted Storks, 60 nests were monitored from the period of egg laying through dispersal of young ones. Weekly data were taken on the number of eggs, number of chicks, survival of chicks and fledging of chicks. The water level around the nesting site was recorded regularly by marked wooden sticks. As all the nesting trees were located on mounds surrounded by water, nest counting was done by boat. Counting of total nests and adults were done at the time of roosting, thrice in each nesting colony.

Intensive vegetation sampling was done at all the feeding sites of each of the four species of storks. A systematic random sampling design was followed. At each sampling point, a 0.5 m x 0.5 m quadrat with 25 subdivisions each of 10 x 10 cm was used to record presence and absence of species and cover values. A total of 50 plots were sampled at each site. Plots were placed at 5 metre intervals.

The feeding sites of Whitenecked stork were shallow water bodies between forested areas. These sites were sampled for trees, shrub and ground cover of the different plant species. Point-centred-quarter (PCQ) method (Muller-Dombois & Ellenberg, 1974) was used to sample trees and shrubs.

Each nesting tree was sampled for knowing the detailed vegetation structure which can be later interpreted in terms of selection strategies. Sampling was done around each nesting tree by using belt transect of 6 m (3 on both sides) width and 30 m length in four directions from the nesting tree. All the trees within this transect were identified. Measurements were taken from each tree for GBH (girth at breast height), height, tree species and canopy spread. Nest material and nest dimensions were also recorded.

All behavioural observations were taken using focal animal sampling method (Altman, 1974) where a single individual was followed throughout the observation period. Once in a week, one full day observation was carried out to study different hours of the day.

The Blacknecked Stork forages in shallow waters, walking slowly with measured steps and probing in water and submerged vegetation. The time spent in handling was related to the size of the prey species.

Feeding behaviour of the Painted Stork was linked closely to environmental conditions such as presence or absence of aquatic vegetation and water turbidity. In calm, low turbidity areas the bird walked slowly with bill dipped in water and on touching a prey the bill was closed immediately. Unlike many wading bird species that forage visually, it feeds by tactolocation. They walk through water with bills open and partially submerged and they catch fishes encountered during the activity, but this feeding strategy requires high densities of prey.

Openbill Stork usually feeds by tactile or visual methods (Kahl, 1971b). The staple diet of Openbill Stork is *Pila* which is quickly extracted by its probing bill without breaking the shell.

The Whitenecked Stork forages by walking slowly or standing, visually searching for prey in puddles or small water bodies in forested areas and grasslands. Due to shy behaviour of the Whitenecked Storks, substantial amount of data could not be collected to compare with other species.

There was large variation in the diet spectrum of Blacknecked Stork and other stork species. The food species recorded in the diet of Blacknecked Stork were birds such as Shoveller (*Anas clypeata*), coot (*Fulica atra*) and chicks of Pheasant-tailed Jacana (*Hydrophasianus chirurgus*); four species of fishes; Lanchi (*Wallago attu*), Singhi (*Heteropneustes fossilis*), Saul (*Channa striatus*) and Rohu (*Labeo rohita*); insects such as dragonfly; and snakes such as Checkered keelback (*Natrix piscator*). Some unidentified small food items were also taken.

The Painted Storks were observed feeding on fishes, the identification of which was not possible as they gulped them quickly, while Openbills mostly feed on *Pila.*

The Principal Component Analysis (PCA), an ordination technique was performed on the foraging variables of Blacknecked Stork. The first three factors explained 67% of the total variation in data. The first factor explained 30% variation, showed high loading for water level, steps and food species. The second factor accounted for 20% of variation showed high loading for food size and nearest species. Third component explained 16% of variation showing high factor loading for species distance.

In Painted Stork, the first three PCs explained 67.3% of the variation in the foraging variables. The first component accounted for 35.9% of the total variance and showed high positive correlation with steps, grass height, group size and water level. The second component accounted for 20.4% of the total variance. This component was highly correlated with grass height and group size. The second component accounted for 20.4% of the total variance. This component was highly correlated with grass height and group size. The third component accounted for 11% of the total variance. The highest positively correlated factors were inter-specific distance and shore distance.

The PCA extracted three components with total variance of 57% in Openbill Stork. The first PC was positively correlated with inter-specific distance and distance to shore. The second component accounted for 20% of the variance. This component was positively correlated to steps and peck rate. The third component accounted for 14% of the variance. This factor accounted for highest variability in group size and distance to shore.

Total of 15 nests of Whitenecked Stork were found during 1994-1996. Of the 15 nests found, two were selected for intensive study on the behaviour of the birds. The mean height of the nests from the ground was (mean $\pm$ s.d.) 4.5 $\pm$ 1.3 m (n=6). The nests were constructed from dead sticks of *Mitragyna parvifolia* with lining of grasses and were deep enough to hide the chicks. The mean depth, length and breath recorded for the nests were 14.74 $\pm$ 10.50, 93.45 $\pm$ 41.19, 67.97 $\pm$ 39.93 (n=4) cm.

Both sexes take part in nest construction and incubation. Although there was no sexual dimorphism, on closer observation from the hide, the colour differences on the face of the adults were clear. The incubation period recorded was 30 days.

The chicks were brooded for about a week by the adult and they were not fed for four days. The chicks were young and vulnerable so the parents were always there till the age was 33 days, chicks left the nest.

The calculated percentages of activities performed on the nest by male and female Whitenecked Stork during different stages of chicks revealed that there was no difference in the time spent on activities by the two sexes. There was no significant difference for parental investment between the two sexes (P>0.001).

In total 12 nests of Blacknecked Stork were located inside the Park. Two accessible nests were selected for intensive study. The observation on the courtship and incubation were taken from the dyke with telescope and hide was placed after hatching. The mean depth, length and breadth of the nests recorded were 133.84 ± 32.66, 109.3 ± 39.99, 19.5 ± 12.62 (n=5) cm (mean ± s.d.) respectively. The mean time spent on mating was 15.11 ± 5.08 (n=9) seconds. The incubation period recorded was around 45 days. The chicks were guarded for a long time by the parents. After 60 days, the juveniles left the nest. There was no significant difference (p>0.0001) between the parental investment of a male and a female Blacknecked Stork in chick rearing.

A total of nine species of trees were recorded at the foraging sites of Whitenecked Stork. *Acacia nilotica* occurred in highest density i.e. 46.2 trees/hectare and was the only species with an IVI of 180 followed by other dominant species. The foraging site of Blacknecked Stork and Whitenecked Storks differ to a great extent in the composition of plant species. Wetland areas with more aquatic vegetation such as *Paspalum distichum*, *Eleocharis dulcis*, *Echinocloa colonum* and *Cyperus rotundus* were frequently utilised by the Blacknecked Stork.

There was significant difference (X^2 = 34.75, p<0.001) in mean water depth of the foraging sites of Blacknecked and Whitenecked Storks.

There was slight difference in the foraging sites of Painted and Openbill Storks. All the feeding sites of Painted Stork were characterized by area where aquatic vegetation comprised of algae, *Ipomea aquatica*, *Hydrilla verticillata*, *Echinocloa* and *Eleocharis dulcis,* whereas Openbill Stork fed at sites dominated by species such as *Paspalidium* and *Vetiveria zizanoides.*

The habitat utilized for nesting by the Blacknecked and Whitenecked Storks differed to a great extent in terms of species preference and location of nest on the tree. The Blacknecked preferred top canopy of the tree while Whitenecked Stork nested in the middle, dense, hidden strata of the tree.

I performed Principal Component Analysis (PCA) on all variables of the nest-site charateristics. The first three PCs explained 70% of the total variance. The first PC is highly positively correlated with canopy spread, GBH (Girth at Breast Height) and distance to road from the nesting tree. The second component accounted for an additional 27% of the total variance and third component accounted for 13% of the total variance and was highly positively correlated with water level.

There was significant difference (p<0.0001) between the nesting and non-nesting trees of Blacknecked Stork.

The nest-site variables for Whitenecked Stork explained 98% of the variance. The first component accounted for 51% of the total variance. The first P is highly positively correlated with GBH, water source outside the Park and distance to road from the nesting tree. The second component accounted for an additional 36% of the total variance. This component was positively correlated with canopy spread, distance to nest of other species and water source outside the Park. The third component accounted for 11% of the total variance. Tree height was positively correlated with this factor.

There was significant difference (p<0.0001) between height, canopy spread and GBH of nesting and non-nesting trees of Whitenecked Storks.

I took observation on the behaviour of the four species of storks. Not much information could be collected on the four species as Painted, Openbill, and Whitenecked Stork leave the Park after January, while Blacknecked Stork is the only species that stays in the Park throughout the year. The t-test showed no significant difference (p>0.0001, df=2851, t=1.6198) in the activities of male and female Blacknecked Storks.

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TITLE **Ecology, biology and ethology of Greater Adjutant Stork *Leptoptilos dubius* (Gmelin) in Assam, India**

STUDENT **Hilloljyoti Singha**
GUIDE **Asad R. Rahmani**

YEAR **1998**

UNIVERSITY **Aligarh Muslim University**

Summary

Of the 20 stork species in the world, the Greater Adjutant Stork *Leptoptilos dubius* is perhaps the most endangered. Earlier widespread in northern and north-east India, Nepal, Bangladesh, Myanmar, Cambodia and southern Vietnam, this stork is now largely localized in the Brahmaputra Valley, Assam. In the mid 1980s its precarious status was highlighted, and since then, some work has been done in Assam.

Before I started work in 1994, except for some basic information there was no detailed study about the ecology, biology and behaviour of the Greater Adjutant Stork (GAS). The objectives of my study were to know the present status and distribution of the GAS throughout the Brahmaputra Valley, during breeding and non-breeding seasons and to know the nesting ecology, breeding biology and flocking behaviour of GAS during the non-breeding season.

My study was confined to the Brahmaputra Valley, Assam. I did intensive study on nesting ecology and breeding biology at Nagaon, in middle Assam, and studied the flocking behaviour at Guwahati and Nagaon garbage dumps.

At the outset of my study, I did an extensive survey of populations as well as nesting colonies of GAS throughout the Brahmaputra Valley during the breeding season of 1994-95. The survey was of roadside counts, following the national highways as well as interior places on motorcycle. Information from literature and locals were taken to survey the nesting colonies.

During the non-breeding season, the Greater Adjutant Storks gather on garbage dumps. A random summer census (June to July 1996) was carried out in nine townships which were situated on both the banks of the Brahmaputra river.

Simultaneously with the survey of nesting colonies, during 1994-95 breeding season, I also collected data on the nesting ecology. In the next two subsequent nesting seasons (1995-96 and 1996-97) I intensively studied the nesting ecology of GAS in North Haibargaon nesting colony at Nagaon.

Throughout the Brahmaputra Valley, the nesting trees as well as non-nesting trees (within a radius of 10 m around each nesting tree) were identified and their architecture which included height, diameter at breast height (DBH) and canopy spread were measured. The number of nest(s) on each tree was counted. The nearest nesting tree distance (NNTD) was measured.

The ground cover (shrubs and grasses) below each nesting tree was measured and categorised into five types and the dominant vegetation around the 25 m radius of each nesting tree was recorded. The distance of other habitat parameters - nearest house, nearest forest, nearest road, nearest water source and nearest foraging ground from the nesting tree was measured.

The same method of nesting ecology was applied in the intensive study area, however here the non-nesting trees were measured within the 25 m radius around each nesting tree.

The study of breeding biology of the Greater Adjutant Stork was done in the intensive study area for successive breeding seasons (1995-96 and 1996-97). Meteorological information was collected from Regional Agricultural Research Station, Shillongoni, situated near the colony. Same method was applied in both the seasons.

Daily monitoring of storks was done twice a day (morning and evening) since their arrival to the colony at the commencement of each breeding season up to their departure from the colony at the end of each season. A watch tower (*machan*) was constructed in each breeding season to observe the colony as well as some focal nests from the initiation of nest building till the nests were vacated or abandoned. The focal pairs were observed continuously from dawn to dusk (0500 to 1700 hr) each day, six days a week. Individuals of each focal pair was identified by their natural markings, facial and bill pattern and individual idiosyncrasies. Time budget of the parents on the nest was done till the fledging of the last juvenile from the nest. Reproductive success of the whole colony in each year was found out on the basis of daily monitoring with the help of a field assistant.

I studied flocking behaviour of the Greater Adjutant Stork after the breeding was complete when they gathered on some regular foraging sites. I studied two sites: Urban Garbage Dump near Guwahati and Rural Garbage Dump in Nagaon in June and July 1996 respectively. Ten full day observations were done at both sites from morning through evening (0600 to 1800 hr) without any break by Scan Sampling Method.

All the analyses were done by STATA 5.0 and PREFER programs.

Out of the 17 districts surveyed in the Brahmaputra Valley, 470 Greater Adjutant Storks (411 adult and 59 young) were counted in seven districts during the 1994-95 breeding season. A total of 440 storks (295 adults and 145 juveniles) were counted during the non-breeding season (1996) in nine selected townships.

Nine nesting colonies with 65 active nests on 29 trees were found during the survey of 1994-95 breeding season in five districts of the Brahmaputra Valley. Except one nesting colony found in the riverine forest, all the colonies were found in villages and semi-urban areas. The distances habitat parameters - NNTD, nearest house, nearest road, nearest forest, nearest water source and nearest foraging ground were found close to each nesting colony.

Throughout the Brahmaputra Valley as well as in intensively studied colony at Nagaon, the tree architecture of the nesting trees was greater than that of the non-nesting trees. Tree architecture of nesting and non-nesting trees of different species and in different colonies was significantly different. At the intensive study colony, the nesting trees with larger number of nests were larger and taller than the trees with lesser number of nests. The number of nests was highly correlated with height, DBH and canopy spread of the nesting trees.

The Principal Component Analysis (PCA) reveals that all variables show a moderate correlation with PC-I and PC-II. The first two components cumulatively explained 75% of total variance. It was found that nearest water source and foraging ground were more positively correlated to PC-I.

Throughout the Brahmaputra Valley, the more frequently used nesting tree species were *Alstonia scholaris* and *Mitragyna parvifolia* among the eight nesting tree species found during the survey. At Nagaon in the intensive study area, 10 species of trees were used for nesting. It seems that at Nagaon GAS preferred *Bombax ceiba* to other trees. Most of the nesting trees had 100% ground cover, and bamboo was the dominating vegetation.

It is assumed that most likely the Greater Adjutant Stork prefers to nest in a compact colony on large, widely branched trees with thin foliage cover amidst thick vegetation cover below the tree, preferably by bamboo "screen", near food and water sources on traditional sites with minimum human disturbance.

The study of breeding biology reveals that most of the breeding behaviour of the Greater Adjutant Stork are similar to other species of stork. In almost all aspects of breeding biology, the GAS resembles its congeneric Marabou Stork *Leptoptilos crumeniferus.*

The GAS lays one to four eggs ($x = 1.9 \pm 0.74$ SD; $n = 50$) with two-eggs clutch most frequent. Both the parents incubate. The incubation period is around 35 days. The chicks hatch asynchronously with one or two days interval. The parent GAS regurgitate food on the nest floor to feed the young. Right from the hatching, the chicks were found to be voracious feeders. The whole-vertebrate food (fish, amphibians, reptiles and birds) were brought to the nest, supplemented by offal at the juvenile stage.

The chicks grow rapidly during the initial period of their life. Both the parents share guarding the nest alternately during which they clean and repair the nest, nurse the chicks by shading and preening. As the chick grows, the attendance of parents on the nest decreases. A six weeks old chick can defend itself and at this stage parents start to be away from the nest sometime at night also.

The young GAS attain juvenile stage at the age of nine weeks. They leap in the air from the nest floor with vigorously flapping wings. Though the juveniles are capable of flying they still come back to the nest to be fed by the parents. They ultimately fledge asynchronously.

Different trips made by the parents from the nest were related to the age of the young and time of the day, the frequency of nest material trip and foraging trip increasing when the young ones were 50 to 60 days old. These trips were more frequent in the middle part of the day.

The average fledging period of the young GAS is about 142 days from the day of hatching. The overall breeding season (September through May) of the whole colony is comparatively larger than other storks.

Seventy-two young fledged out of 93 hatchlings during the study period giving overall fledging success of 77.42%. On average 0.87 ± 0.97 SD ($n = 83$) young fledged per nest.

Chick mortality was found to be more among the late breeders. The causes of chick mortality appear to be starvation, weather extremes, accidental fall from the nest and aggression of other GAS.

The result of the flocking behaviour study during non-breeding season, which is very brief compared to the long breeding season, shows that the Greater Adjutant Storks form very compact flocks. Synchronization of activities was noticed which shows flock cohesiveness. It was observed that during the non-breeding period, at garbage dumps, most of the storks pass the day resting and feeding. There was a significant difference of adults and juveniles, particularly in foraging activities. Most of the activities of the GAS at two different places were significantly different, which shows that habitat condition can influence the behaviour of GAS. It seems that weather fluctuation has very little impact on the activities of storks in garbage dump. Except for some activities, the general trend of the storks involved in different activities at garbage dumps remained almost similar at different time of the day.

It seems that the Greater Adjutant Storks are opportunistic feeders and forage in different habitats according to the food availability.

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TITLE **Feeding ecology of some wading birds in the Gulf of Kachchh**
STUDENT **V. J. Bhuva**
GUIDE **Prof. V.C. Soni**
YEAR **1999**
UNIVERSITY **Saurashtra University**

Summary

The Gulf of Kachchh is an important area for migratory as well as resident bird species. The vast coastline is very rich in marine life and it supports a wide variety of coastal birds. However, the Gulf of Kachchh is less explored by researchers for studying the ecology of wading birds in particular, as wading birds are one of the most important part of marine ecology. To fill up the lacuna in the knowledge on ecology of wading birds in the Gulf of Kachchh, this study was carried out.

Among the bird species studied during this study, Crab Plover and Curlew fed in intertidal area and Black-tailed Godwit and Avocet fed in salt-pans. In the Gulf of Kachchh, Crab Plover, Curlew, Black-tailed Godwit and Avocet are very common and also found in large numbers, that is why Crab Plover, Curlew, Black-tailed Godwit and Avocet were selected for the study of their feeding ecology.

Narara Island and Rozybundar are situated on the southern coast of the Gulf of Kachchh and have good intertidal zone with very rich biodiversity as well as salt-works in large numbers. Both provide more or less similar type of feeding habitat and roosting to waders. That is why Narara Island and Rozybundar were found suitable for the study. However, comparatively Rozybundar shows more human activities.

More than 80 species of birds are found in the Gulf of Kachchh. The birds roosted on the ground above the high tide which was convenient for the bird census which was carried out by visual count. Monthly observations show that birds preferred less disturbances on roosting and foraging grounds. Because of this the population of wading birds was higher on Narara Island than at Rozybundar.

Crab Plover spent more time for standing activity compared to the other foraging activities like walking, feeding attempts etc. Compared to Crab Plover number of successful and unsuccessful feeding attempts in a minute was higher because curlew used more exhaustive foraging method like walking slowly whereas Crab Plover used walk-stop-look method for foraging.

As the large sized prey required more time for handling, moreover the prey very often lost by kleptoparasitism, that is why the Crab Plover takes relatively smaller sized prey species. Crabs from the Xanthidae family was comparatively smaller in size and it was the major diet of Crab Plover. In regurgitated pellets (n=50) occurrence of *Playtipodia cristata* and *Etisus laevimanus* were higher, compared to the other crab species like *Neptunus sanguinolentus*, *Charybdis lucifera, Eurycarinus orientalis* and *Pagurus* sp. Major diet of Curlew was Fiddler crabs (*Gelasimus annulipes*) (93.71%) and *Artemia salina* was the main food species of Black-tailed Godwit and Avocet, which was found in salt-pans.

Average size of the major diet of Black-tailed Godwit and Avocet was smaller than average size of the major diet of Crab Plover and Curlew, feeding attempts of Black-tailed Godwit and Avocet were very high. Successful feeding attempts of Black-tailed Godwit and Avocet were higher than unsuccessful feeding attempts.

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TITLE **Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India**
STUDENT **T.R. Shankar Raman**
GUIDE **Prof. Sukumar**
YEAR **2001**
UNIVERSITY **Indian Institute of Science**

Summary

The proper study and interpretation of bird community structure requires the use of appropriate methods to census birds. In the temperate region, the three most commonly used techniques of bird census are line transects, point counts, and territory spot-mapping. For tropical rainforests, particularly in south and south-east Asia, there have been few applications and assessments of different census techniques for use on bird communities. The effort made during this study to redress this lacuna (Chapter 3) suggests that, across species, the two methods most commonly used to census birds, namely line transects and point counts, yield density estimates of rainforest birds similar to, but slightly higher than, those obtained by more intensive spot-mapping. Estimates of relative abundance of bird species were similar in all three methods. Although spot-mapping is the method of choice for determining density and distribution of territorial birds, the point count technique was particularly suitable for application in this study. This was because it allowed a greater coverage of areas within the limited time, enabled obtaining replicate samples useful for statistical analyses, and helped survey birds in small fragments and rugged terrain with comparative ease. These advantages outweighed problems such as the possible overestimation of density of common bird species due to their mobility and inclusion cumulatively during the count period. There is a need to further test these methods for density comparisons between habitats and time period. Point counts standardised for effort, in particular, may be useful for monitoring long-term trends of rainforest bird populations in rugged terrain and habitat remnants in the Western Ghats.

The greater part of this study involved describing tropical rainforest bird community structure and its patterns of variation across a variety of settings. In Chapter 4, I attempted to describe how bird community structure varies along an elevational gradient in a landscape relatively undisturbed by human action (in the Kalakad-Mundanthurai Tiger Reserve). Although bird species richness was not found to vary substantially with elevation, there was pronounced turnover of bird species leading to community composition being very different at higher elevations as compared to lower elevations. The occurrence and turnover of species was correlated with elevation and tree species composition of three sites, did not appear to be due to stochastic factors. This argues for a significant influence of deterministic factors in bird community structure and weakens the possibility that rainforest bird communities are merely non-equilibrium communities produced by the chance assembly of species. The generality of this finding is supported by similar results obtained by some earlier studies as well as by the results in Chapter 5 and Chapter 6, which also argue for the importance of deterministic factors, particularly tree species composition and habitat structure, in determining rainforest bird community structure.

Community ecologists have attempted to circumvent the difficulties of performing large-scale experimental studies or perturbations of community structure by developing procedures to simulate these processes using computers. It has often been suggested that patterns observed in nature may arise from the simple operation of chance factors (such as the random colonization of a site by a set of species from a larger species pool) and such 'null' models may have to be first evaluated as the most parsimonious explanation for patterns. A hierarchy of null models, varying in complexity and in the number of constraints imposed, were evaluated to determine if observed patterns of community similarity between sites (Chapter 4) and

species richness across fragments (Chapter 6) were reproduced under the operation of such chance or non-equilibrium dynamics. The results clearly suggest that null models with few or no constraints do not reproduce the observed patterns and trends. A degree of realism enters these models when biological constraints reflecting limitations of species richness at sites or the distributional ecology of species are factored in. The results therefore argue for a greater representation of biological constraints in future models and theoretical developments in the field of bird community ecology. These models need to build on the foundation of knowledge on the natural history and ecology of individual bird species.

Earlier research has emphasized the value of lowland and low-elevation forests for conservation, as these were believed to be areas containing the greatest number of species as well as species with narrowly-restricted ranges. The present study illustrates that in the Western Ghats, mid- and high-elevations (up to 1,400 m) may also have equivalent levels of bird diversity, and that endemic species with narrow ranges occur at both limits of the elevational gradient. The substantial turnover in species with elevation suggests that areas encompassing all elevation zones must perforce be included for bird conservation to be effective. Of various habitat attributes, the maintenance of rainforest tree species composition at specific elevations appears particularly important for the maintenance of bird communities typical to the region.

The alteration of rainforests habitat results in clear and discernible changes in bird community structure. At scales within that of a patch of secondary forest (Chapter 5) or fragment of rainforest (Chapter 6), bird species richness and community similarity with undisturbed rainforest are dependent strongly on habitat structural attributes such as woody plant density, canopy cover, and vertical stratification. This effect is at least partly mediated by the effects of habitat structure on bird abundance — with sites containing well developed habitat structure managing to support greater densities of rainforests birds. The bird species composition of such disturbed areas was again, as mentioned earlier, dependent on tree species composition besides other factors such as elevation and distance from the source pool. This has important implication as it indicates that even secondary forests and small fragments, particularly where they retain habitat structural and floristic attributes (e.g. Pannimade, 10 ha, Chapter 6), can act as refuges for rainforest birds in the landscape. Thus, direct effort for bird conservation should include rainforest restoration efforts focusing on enhancing the structural and floristic resemblance of secondary forests and fragments with relatively undisturbed rainforests.

At a larger spatial scale of the entire landscape too there are marked changed in the species pool and bird communities. In the rainforest-dominated landscape of the Agasthyamalai hills, for instance, there were only two non-rainforest species that occurred only in disturbed or secondary rainforest habitats such as the abandoned plantations (Chapter 5). This is in sharp contrast to the highly man-modified landscape of the Anamalai hills, wherein there were at least 25 open-country species derived from drier deciduous forests and scrub jungles that had not only colonized plantations, but also used rainforest fragments (Chapter 6). Although the differences in species composition were partly due to the less disturbed habitat structure in the abandoned plantations in the Agasthyamalai region than in the rainforest fragments in the Anamalai hills, the effects of the larger landscape are also manifest.

It is also clear from this study that all species are not equally susceptible to habitat alteration or fragmentation. The extent of change due to habitat alteration in bird species populations, assessed by the persistence index in this study, depended on attributes such as diet-guild, endemism, and body size. Various attributes of species influenced their persistence — species that are larger, rarer, or more restricted in distribution (endemics and priority species, Chapter 6) tended to be more vulnerable to human-induced habitat alteration. Species responses were also linked to their dietary ecology and habits — birds such as terrestrial insectivores, bark-surface feeders, carnivores, and frugivores (Chapters 5 and 6) appeared to be more vulnerable to changes in the habitat. Such variations across species may be utilized to more effectively target conservation and monitoring efforts at the more vulnerable species.

Landscapes such as the Anamalai ranges, containing fragments of rainforest in a matrix of plantations, pose several challenges for conservation. Where fragment size falls below a threshold of 10 ha, there are significant declines in rainforest bird species richness. Although medium-sized fragments (10-100 ha) may not contain all species, particularly large raptors, they hold populations of a majority of rainforest bird species. This is also true, to a lesser extent, of coffee estates that retain rainforest trees in the canopy for shade.

As such sites help support larger populations of rainforest birds in man-modified landscapes, and increase connectivity between patches or wide-ranging birds in latitudinal migrants, they need to be included in bird conservation plans as potential refuges for birds.

Several aspects pertinent to the study of rainforest bird communities remain to be elucidated. A few which I consider particularly important are highlighted here. There is a need for further application and assessment of bird census methods and field techniques through comparisons between habitats and across years for particular species. Species vulnerable to habitat alteration, such as the Malabar Trogon, woodpeckers, terrestrial insectivores, and flycatchers, may be targeted for intensive ecological studies and monitoring. Territoriality, area-requirements, social organisation, multi-species flocking, behaviour, and plot occupancy patterns of virtually all resident rainforest bird species remains to be described and this will require in most cases the use of capture and ringing studies. There is also an urgent need to apply these techniques to monitor long-term trends in bird populations, to identify species that may be declining (towards extinction) and unravel underlying causes. The effects of elevation on bird communities need to be further explored by including areas at lower and higher elevations than was possible during this study. To what extent competition plays a role in community structure and elevational distribution patterns is also still an open question that could be the focus of fascinating studies. Studies on bird demography and dispersal are also needed to understand the processes underlying the colonization and extinction of species, particularly in disturbed secondary habitats, regenerating or restoration areas, and rainforest fragments. This is also likely to yield insights into factors governing the temporal dynamics of bird communities. The effects of the surrounding landscape matrix on rainforest bird populations need to be explored across a variety of landscapes in the Western Ghats. At a much larger level, there is a need to compare bird communities of the Western Ghats with other tropical forest regions to see to what extent there are generalities, similarities, or divergencies in bird community structure and its variation over space and time.

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